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ASTRONOMY.

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SCOTT'S FIRST BOOKS IN SCIENCE.

FIRST BOOK
OF
ASTRONOMY:

WITH QUESTIONS ON EACH PAGE, AND A DICTIONARY OF TERMS.

BY
JOHN L. COMSTOCK M.D.
AND
RICHARD D. HOBLYN A.M. Oxon.
AUTHOR OF MANUALS OF CHEMISTRY, THE STEAM ENGINE, ETC.

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FIRST BOOK OF NATURAL PHILOSOPHY:

Including, 1. Properties of Bodies.—2. Mechanics.—3. Hydrostatics.—4. Hydraulics.—5. Pneumatics and Steam Engine.—6. Acoustics and Music.

WITH QUESTIONS ON EACH PAGE, AND A DICTIONARY.

By JOHN L. COMSTOCK, M.D., and RICHARD D. HOBLYN, A.M., Oxon.

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The present treatise is the Chapter on Astronomy reprinted from the Authors' Manual of Natural Philosophy, with an introduction explanatory of some matters necessary to be known for its perusal, an Appendix of Astronomical Problems, and a Dictionary of Terms extracted from the Dictionary appended to the Manual.

It is now admitted that works intended for First Books in Science, and Class-Books in Schools, ought not to be written in a style professedly adapted to the capacities of children; but that intelligence in the reader should be assumed, and that if the principles of science be so explained as to be understood by those who have acquired no previous knowledge on the subject, young persons of ordinary capacity will be capable of comprehending them. Therefore, when the importance of any branch of education is admitted, there are but two requisites to its attainment, viz., clearness on the part of the writer, and an ordinary and sustained effort of thought on the part of the reader. Each party is entitled to make the respective demand, and, if the demand be mutually satisfied, the success of the experiment may be fairly relied on.

It has been said, it is believed with great truth, that few writers excel Dr Comstock in clearness, simplicity, and precision, of which the readers of this treatise can judge for themselves. It is presumed to be not an unfavourable specimen of what a First Book in Astronomy ought to be. It is therefore presented by the publisher as the first of a series of elementary Text Books, intended to be published by him, on those branches of science which it is presumed might be advantageously introduced in schools, as preparatory to a more finished education, and for students intended for the learned professions. These First Books will also be adapted for those desirous of attaining the elements of science in a systematic manner, without the assistance of teachers, at as little expense of time and money as the subjects will admit. For these purposes, they will be written in easily intelligible language, yet so as not to sacrifice truth to ornament, nor to substitute sentimentalism for science; the object kept in view being to convey as much knowledge of the several subjects as will suffice for elementary instruction, and enable those desirous of extending their information to pursue their future inquiries with advantage.

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INTRODUCTION.

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1. In proposing to the youthful student a scientific inquiry, so extensive in its design, so inexhaustible in its details, as Astronomy, the author's first endeavour should be directed to the removal of every unnecessary difficulty. Every one who has been engaged in the pleasing, yet anxious, task of instruction, is painfully sensible of the tendency exhibited by young persons to start aside at the first expression which calls upon them to *think;* and to close a work, though containing matters of the deepest intellectual interest, the moment it ceases to be *amusing.* In such cases, a picture or a tale is found to attract, while a diagram, or the plain statement of a scientific truth excites aversion. The habit of seeking entertainment in books, grows with our growth, until we find ourselves actually incapacitated for the enjoyment of rational pursuits, or the due appreciation of moral truth. This fatal tendency is strengthened and matured by prejudice: whatever savours of science, of philosophy, is thought to have been placed beyond our reach; the vulgar notions on subjects with which the vulgar have never grappled, are transmitted from generation to generation, and are even paraded with an ostentation of humility; meanwhile the mind, in many cases capable of better things, is compelled to seek for recreation in pursuits of unprofitable, if not of more questionable tendencies.

2. On this subject, how judicious are the words of an *eminent* modern writer. "In entering upon any scienti

pursuit, one of the student's first endeavours ought to be, to prepare his mind for the reception of truth, by dismissing, or, at least, loosening his hold on all such crude and hastily adopted opinions respecting the objects and relations he is about to examine, as may tend to embarrass or mislead him; and to strengthen himself, by something of an *effort* and a *resolve*, for the unprejudiced admission of any conclusion which shall appear to be supported by careful observation and logical argument, even should it prove of a nature adverse to notions he may have previously formed for himself, or taken up, without examination, on the credit of others. Such an effort is, in fact, a commencement of that intellectual discipline which forms one of the most important ends of all science. It is the first movement of approach towards that state of mental purity, which alone can fit us for a full and steady perception of moral beauty as well as physical adaptation. It is the 'euphrasy and rue' with which we must 'purge our sight,' before we can receive and contemplate, as they are, the lineaments of truth and nature."—*Herschel's Astronomy.*

3. To awaken curiosity and then to gratify it, so as to induce a habit of intelligent thoughtfulness in the pupil, is the happy end obtained by the successful teacher. To attain this end, an appeal is made to a common principle of human nature. An eloquent writer has observed, that every being is by nature endowed with the power of gaining knowledge; that the taste for it—that is, the capacity to be pleased with it—forms equally a part of the natural constitution of his mind; and that it is his own fault, or the fault of his education, if he derive no gratification from it. "If it be a pleasure," he observes, "to gratify curiosity—to know what we were ignorant of—to have our feelings of *wonder* called forth, *how pure a* delight of this very kind does natural science *hold out to its students!* Recollect some of the *extraordinary discoveries of* mechanical philosophy. How wonderful

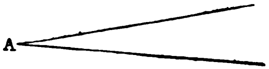
are the laws which regulate the motions of fluids! Is there any thing in all the idle books of tales and horrors more truly *astonishing* than the fact, that a few pounds of water may, by simple pressure, without any machinery, by merely being placed in a particular way, produce an irresistible force? What can be more *strange* than that an ounce weight should balance hundreds of pounds by the intervention of a few bars of iron? Observe the *extraordinary* truths which optical science discloses. Can any thing *surprise* us more than to find that the colour of white is a mixture of all others—that red, and blue, and green, and all the rest, merely by being blended in certain proportions, form what we had fancied rather to be no colour at all, than all colours together? Nor is chemistry behind in its *wonders*. That water should be chiefly composed of an inflammable substance—that acids should be for the most part formed of different kinds of air—and that one of these acids, which can dissolve almost any of the metals, should consist of the self-same ingredients with the common air we breathe—that salts should be of a metallic nature, and composed chiefly of metals, fluid like quicksilver, but lighter than water, and which, without any heating, take fire on being exposed to the air, and by burning form the substance so abounding in saltpetre, and in the ashes of burnt wood—these, surely, are things to excite the *wonder* of any reflecting mind, nay, of any one but little accustomed to reflect. And yet these are trifling when compared with the *prodigies* which Astronomy opens to our views—the enormous masses of the heavenly bodies, their immense distances, their countless numbers, and their motions, whose swiftness mocks the uttermost efforts of the imagination. Is it not in the highest degree interesting to find, that the power which keeps the earth in its shape, and in its path, wheeling upon its axis and round the sun, extends over all the other worlds which compose the universe, and gives to each its proper *place and* motion; that this same power keeps the moon in her path round our earth, and our earth in its path round the sun, and each planet in its path; that the same power causes the tides upon our globe, and the peculiar form of the globe itself; and that, after all, it is the same power which makes a stone fall to the ground? To learn these things, and to reflect upon them, occupies the faculties, fills the mind, and produces certain as well as pure gratification."—*Objects, Advantages, and Pleasures of Science.*

4. It must not, however, be supposed that there is any "royal road" to science; nor, because the present work is termed a First Book of Astronomy, is it therefore to be considered a play book for children. The subject is eminently and confessedly worthy of attention, and the labour expended in mastering the subject will bring its own reward. One recommendation of the present volume may, without presumption, be anticipated: if it be true, that "a great book is a great evil," it is at least equally true that a small book is a less evil; a hope may perhaps be entertained that the small book, if it contain the matter of the great one in miniature, may become a positive good. Let not the ability or the taste of the young mind be *underrated;* let the importance of truth, —of truth *for its own sake*,—apart from the discouragement of punishment or the stimulus of reward, be placed before it; let it be early understood, that in the attainment of knowledge, as in that of wealth, a certain amount of labour must be encountered; but let it be further inculcated, that in the former pursuit, though not in the latter, the result is certain, the enjoyment unquestionable.

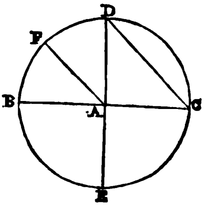
5. The difficulties, or, to use a more pleasing term, the *novelties* of a science, present themselves at the threshold of the inquiry. If met with the ordinary *curiosity* which trifling subjects excite, they vanish, and are seen no more. The first step gained, each successive step becomes more easy, more agreeable. Upon a few simple truths connected with the grand subjects of *space* and *numbers*, has been constructed

the noble science of Mathematics—a science depending more on reasoning than on observation. Mathematics is, in short, a learned name of that science which treats of whatever can be *numbered* or *measured*, and it is divisible into two branches, the one arithmetic, or the science of number, the other geometry, or the science of figure. Mathematical language, as applied to astronomical observations, is found to be the shortest, the simplest, and the most easily understood of any. In order to facilitate the progress of the reader, the first principles of this science are here explained.

6. *First Principles.*—Since the principal part of practical astronomy consists in the measurement of angles, it is necessary that the nature of an angle be clearly understood. When two lines, situated in the same plane, but having different directions, meet together, an *angle* is formed, and the point A, from which the lines diverge, is called the vertex or *angular point*. The length of the lines has nothing to do with the measurement of the angle, this term being limited to the inclination of the lines.



7. If one of the points of a pair of compasses be fixed, whilst the other is carried round, the latter point will trace out the *circumference* of a *circle*, of which the fixed point A is the centre. The circumference of every circle is divided into four equal parts, called *quadrants*, and each of these into 90 equal parts, called *degrees*, so that the whole circumference contains four times 90, or 360 degrees, which are marked °. In order to measure smaller parts of an angle than a degree, the degree is subdivided into 60 minutes, marked ′; and the minute into 60 seconds, marked ″. Thus the whole circumference of the



circle contains 360 times 60, or 21,600 minutes; which multiplied again by 60, gives 1,296,000 seconds.

8. In the above figure, any line, B C or D E, passing through the centre, and having its extremities in the circumference, is a *diameter*. Any line, drawn from the centre to the circumference, as A B, A C, A D, A E, is called a *radius*. Any portion, D C, of the circumference, is called an *arc;* and the straight line joining D C is its *chord*. The figure bounded by an arc and its chord, is called a *segment*.

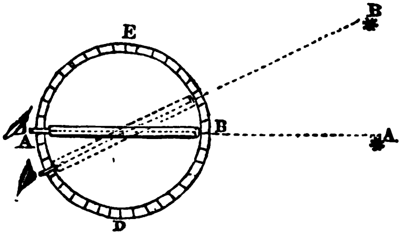
9. A *right* angle is the angle formed by a straight line falling perpendicularly upon another straight line, containing 90 degrees, or the quadrant of a circle, as D A B, or D A C. Hence the four portions of the circumference in the above figure, serve as the measure of four right angles, which comprehend the whole space about the centre. An *obtuse* angle is greater than a right angle, containing more than the quadrant of a circle, or 90 degrees, as E A F. An *acute* angle is less than a right angle, containing less than a quadrant of a circle, or 90 degrees, as D A F.

10. The application of the foregoing principles in practical astronomy is found in the use of the *theodolite*, which is a circular instrument for the purpose of measuring angles contained between lines supposed to be drawn from any point to two distant objects. A very cheap and simple instrument of this kind, for enabling pupils to ascertain the number of degrees in angles formed by distant objects, may be made in the following manner:—

11. "Let a circular piece of wood, eight or ten inches in diameter, be procured. Divide its circumference into 360 equal parts, and mark the degrees. This may be done more accurately if the surface have a sheet of strong white paper pasted or glued on it. A tube made of tin plate, in imitation of a small telescope, having a very small hole, about the size of a pin, in one end, and the other end having two fine wires soldered at right angles to each other, is made to turn round

the centre of the wooden circle, so that it may be directed to a distant object. The instrument being placed on three feet of the proper height, the pupil will be able, in a very few minutes, to measure horizontal angles, and thus get a clear idea of *angular* magnitude.

"The whole will be obvious from the annexed figure, in which A D B E is the divided circle, and A B the tube in imitation of a telescope.



12. "Problem. To find the number of degrees contained in the angle formed by lines drawn from the centre of the theodolite to distant objects A B.

"Direct the tube to the object A, so that it may be opposite the point where the wires cross, and observe the degree or point where the tube crosses the circumference. Turn the telescope till the other object be seen opposite the intersection of the wires, and the number of degrees which the tube has passed over will obviously be the number of degrees contained in the angle A C B.

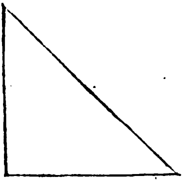
"If a glass tube nearly filled with water be fixed on the side of the tube A B, and parallel to it, a horizontal line may be ascertained. If the instrument be now placed on its stand, with its plane in a vertical position, it may be used for taking angles in a vertical plane."—*Ritchie's Principles of Geometry.*

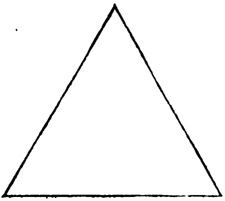
13. The geometrical principles above stated, are frequently

employed in explaining astronomical phenomena. Thus when it is said that the earth revolves upon its *axis*, it is meant that the earth revolves upon an ideal *diameter*, the extremities of which are called the *poles*, or those points, where the diameter meets the circumference, the north pole being that nearest to Europe, the south pole that most remote from it.

14. The *equator* of the earth is a great *circle* on its surface, at an equal distance from each of the poles, dividing it into two hemispheres, in the midst of which are situated the respective poles of the axis. The *plane* of the equator is, therefore, a plain surface perpendicular to the earth's axis, and passing through its centre.

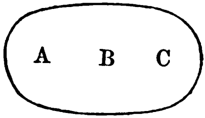
15. A *triangle* is a figure contained by three straight lines, which, at their points of meeting, form three angles. If such a figure has one right angle, it is called a *right-angled* triangle; if the sides are all equal, an *equilateral* triangle. In every triangle, there are six parts to be considered, viz., *three sides* and *three angles;* and if any one side be given with any two angles, or any one angle with any two sides, the other three may be found by geometrical operation. This particular branch of geometry is called *trigonometry*. It enables the astronomer to employ the earth as a base whereby he may measure the magnitudes and distances of the sun and planets; and the navigator on the broad ocean, with no other guide than the stars, to ascertain his exact position on the earth's surface.





16. The earth moves round the sun, not in a circular, but

in an elliptic path. An *ellipsis* is an oval figure, differing from a circle, in having unequal diameters, and in having two points within it, called its *foci.* The foci are the two points A and C in the longest axis of the ellipse, on which, as centres, the figure is described. The *eccentricity* of an ellipse is the distance between the centre and either of the foci, as between B and C.



17. It can hardly be expected that the young pupil will, as a preliminary exercise, enter further into the subject of abstract Mathematics. When he has, however, acquainted himself with the principles already announced, he will find that he has made a certain progress in a science, which lies at the foundation of all accurate reasoning, and will be so far prepared to encounter larger and more elaborate works. *Dimidium facti, qui cœpit, habet.* Let him resolve to overcome the first difficulty, and his future path will be easy and agreeable.

18. *Questions.*—What is an angle? What is the angular point? Is the magnitude of an angle determined by the length, or by the inclination of the lines? How is the circumference of a circle traced? Into how many parts is the circumference divided? How are these parts subdivided? What is a diameter? What is a radius? What relation has a radius to a diameter? Explain the terms arc, chord, and segment? What is a right angle? In what do the obtuse and the acute angle differ from the right angle?

What is the theodolite? How, by means of this instrument, may the angular distance between two remote objects be found? Explain the astronomical terms axis, pole, equator, and plane, with reference to the foregoing principles.

What is a triangle? Explain the difference between a right angled and an equilateral triangle. What is an ellipsis? What is the eccentricity of an ellipsis?

FIRST BOOK OF ASTRONOMY.

OF ASTRONOMY.

1. The term ASTRONOMY denotes the *nomos*, or *law*, which governs the *astra*,[*] or heavenly bodies. Its object is to investigate the magnitudes, distances, mutual relations, and motions, real or apparent, of all the visible bodies of the heavens. This wide field of inquiry has suggested a division of the subject into descriptive, physical, and practical astronomy. 1. "*Descriptive* astronomy demonstrates the magnitudes, distances, and densities of the heavenly bodies, and explains the phenomena dependant on their motions, as the change of seasons, and the vicissitudes of day and night. 2. *Physical* astronomy explains the theory of planetary motion, and the laws by which this motion is regulated and sustained. 3. *Practical* astronomy details the description and use of astronomical instruments, and develops the nature and application of astronomical calculations. The heavenly bodies are divided into three distinct classes, or systems, viz. the solar system, consisting of the sun, moon, and planets; the system of the fixed stars; and the system of the comets."

2. *Systems of astronomy.*—There are several celebrated systems, or hypotheses, for explaining the phenomena of the heavenly bodies. The principal of these are the Ptolemaic, the Copernican, and the Tychonic. 1. The *Ptolemaic* system was so named from the famous geographer Claudius Ptolemæus, who flourished in Egypt during the reigns of the

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1. What does the term astronomy denote? What is its object? How is the subject divided? What does descriptive astronomy teach? What is the object of physical astronomy? What is practical astronomy? How are the heavenly bodies divided? 2. Which are the principal systems of astronomy? Explain the systems of Ptolemy, of Copernicus, and of Tycho Brahe.

[*] *By the term astra*, the ancients understood not only the stars, properly so *called, but also* the sun, the moon, and all the bodies which compose the visible universe.

Roman emperors Hadrian and Antoninus Pius. He taught *that the earth was at rest in the centre of the universe, and that the heavens revolved round it*, from east to west, in twenty-four hours, carrying all the heavenly bodies with them. This system was believed, and enjoyed an undisputed celebrity, for 1400 years. 2. The *Copernican* system derives its name from Nicholas Copernicus, who was born A. D. 1473, at Thorn in Prussia. He taught, as Pythagoras had taught before him, *that the sun occupied the centre of the universe, and that the planets moved round him* in elliptical orbits proportioned to their size. This system was established by the new arguments and discoveries of Galileo, Kepler, and Newton. The great principle on which it rests is gravity, or that force in nature by which all the planets are *attracted to the centre* of their respective orbits. 3. The *Tychonic* system was so named from Tycho Brahe, a noble Dane, who was born A. D. 1546, and who partly restored the system of Ptolemy concerning *the earth remaining at rest, whilst the other heavenly bodies moved round it.* He taught, however, that the moon performed a monthly revolution round the earth; that the sun was the centre of the orbits of Mercury, Venus, Mars, Jupiter, and Saturn, which revolve round him in their respective periods, as he revolves round the earth in a solar year; and, accordingly, that these five planets, together with the sun, are carried round the earth in twenty-four hours. Of these systems, the Copernican is now adopted, as furnishing the most easy and obvious explanation of the various phenomena of the heavenly bodies.

THE SOLAR SYSTEM.

3. The *solar system* comprises the sun, as a centre, and twenty-nine other bodies, which revolve round him in regular periods, and at various distances. These bodies, being perpetually in motion, are called *planets*, from the Greek word signifying wanderers, and they are distinguished, with reference to their centres of revolution, into primary and secondary. 1. *Primary* planets are those which revolve round the sun, as their proper centre. Of these there are eleven: the nearest to the sun is Mercury; then follow in succession,

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3. Of what does the solar system consist? What are the bodies called which revolve round the sun as a centre? What is the difference between a primary and a secondary planet? Which of the planets are attended by satellites, and how many has each?

Venus, the Earth, Mars, Vesta, Ceres, Pallas, Juno, Jupiter, Saturn, and Herschel, or the Georgium Sidus. 2. *Secondary* planets are those which move round some primary planet, as this moves round the sun. Of these there are eighteen: the Earth is attended by one, Jupiter by four, Saturn by seven, and the Georgium Sidus by six. The secondary planets are also termed *moons*, or *satellites*.

4. *Primary planets.*—The following tabular view of the primary planets exhibits their respective diameters, their distances from the sun, the periods of their revolutions round the sun, and those of their revolutions on their own axes:—

Names of the Planets.	Diameters in English miles.	Distances from the Sun in English miles.	Periods of Revol. round the Sun.	Periods of Revolution on their own axes.		
			Days.	D.	H.	M.
Mercury......	3,224	37,000,000	88	15	0	5
Venus.........	7,687	68,000,000	224¾	0	23	21
The Earth...	7,912	95,000,000	365¼	1	0	0
Mars..........	4,189	144,000,000	687	1	0	39
Vesta.........	238	225,000,000	1,335	Unknown.		
Ceres.........	163	260,000,000	1,681			
Pallas........	80	266,000,000	1,680			
Juno..........	1,425	275,000,000	2,008	1	3	0
Jupiter.......	89,170	490,000,000	4,330½	0	9	56
Saturn........	79,042	900,000,000	10,746¾	0	10	16
Georgium Sidus...	35,112	1,800,000,000	30,637¼	0	7	0

5. The following illustration, by Sir J. Herschel, will convey a general impression of the relative magnitudes and distances of the parts of our system. "Choose any well levelled field or bowling green. On it place a globe, two feet in diameter; this will represent the Sun. Mercury will be represented by a grain of mustard seed on the circumference of a circle 164 feet in diameter for its orbit; Venus, a pea, on a circle 284 feet in diameter; the Earth also a pea, on a circle of 430 feet; Mars, a rather large pin's head, on a circle of 654 feet; Juno, Ceres, Vesta, and Pallas, grains of sand, in orbits of from 1000 to 1200 feet; Jupiter, a moderate-sized orange, on a circle nearly half-a-mile across; Saturn a small orange, on a circle of four-fifths of a mile; and Uranus

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4. How long a time does each planet occupy in revolving round the sun?

(Georgium Sidus) a full-sized cherry, or small plum, upon the circumference of a circle more than a mile and a half in diameter. As to getting correct notions on this subject by drawing circles on paper, or still worse, from those very childish toys called orreries, it is out of the question. To imitate the motions of the planets, in the above-mentioned orbits, Mercury must describe its own diameter in 41 seconds; Venus, in 4m. 14s.; the Earth, in 7m.; Mars, in 4m. 48s.; Jupiter, in 2h. 56m.; Saturn, in 3h. 13m.; and Uranus, in 2h. 16m."—*Astronomy*, p. 287.

6. "A *year* consists of the time which it takes a planet to perform one complete revolution through its orbit, or to pass once around the sun. Our earth performs this revolution in 365 days, and therefore this is the period of our year. Mercury completes a revolution in 88 days, and therefore his year is no longer than 88 of our days. But the planet Herschel is situated at such a distance from the sun, that his revolution is not completed in less than about 84 of our years. The other planets complete their revolutions in various periods of time between these; so that the time of these periods is generally in proportion to the distance of each planet from the sun.

7. "All the planets move round the sun *from west to east*, and in the same direction do the moons revolve round their primaries, with the exception of those of Herschel, which appear to revolve in a contrary direction. The paths in which the planets move round the sun, and in which the moons move round their primaries, are called their *orbits*. These orbits are not exactly circular, as they are commonly represented on paper, but are elliptical, or oval, so that all the planets are nearer the sun when in one part of their orbits than when in another.

8. "In addition to their annual revolutions, some of the planets are known to have *diurnal*, or daily revolutions, like our earth. The periods of these daily revolutions have been ascertained, in several of the planets, by spots on their surfaces. But where no such mark is discernible, it cannot be ascertained whether the planet has a daily revolution or not,

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6. What is a year?—7. In what direction do the planets move round the sun? What is the orbit of a planet?—8. What revolutions have the planets besides their yearly revolutions? Have all the planets diurnal revolutions? How is it know that the planets have daily revolutions? What is the axis of a planet? What is the pole of a planet?

though this has been found to be the case in every instance where spots are seen, and, therefore, there is little doubt but all have a daily, as well as a yearly motion. The *axis* of a planet is an imaginary line passing through its centre, and about which its diurnal revolution is performed. The *poles* of the planets are the extremities of this axis.

9. "The orbits of Mercury and Venus are within that of the earth, and consequently they are called *inferior* planets. The orbits of all the other planets are without, or exterior to that of the earth, and these are called *superior* planets. That the orbits of Mercury and Venus are within that of the earth, is evident from the circumstance, that they are never seen in opposition to the sun, that is, they never appear in the west, when the sun is in the east. On the contrary, the orbits of all the other planets are proved to be outside of the earth's, since these planets are sometimes seen in opposition to the sun.

10. "This will be understood by Fig. 1, where, suppose S to be the sun, M the orbit of Mercury or Venus, E the orbit of the Earth, and J that of Jupiter. Now, it is evident that if a spectator be placed any where in the Earth's orbit, as at E, he may sometimes see Jupiter in opposition to the sun, as at J, because then the spectator would be between Jupiter and the sun. But the orbit of Venus, being surrounded by that of the Earth, she never can come in opposition to the sun, or in that part of the heavens opposite to him, as seen by us, because our Earth never passes between her and the sun.

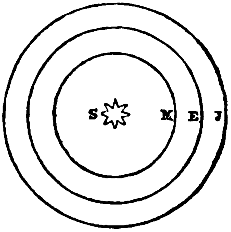

Fig. 1

11. "It has already been stated that the orbits of the planets are elliptical, and that consequently these bodies are sometimes nearer the sun than at others. An ellipse, or oval, has two foci, and the sun, instead of being in the common centre, is

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9. Which are the superior, and which the inferior planets? How is it proved that the inferior planets are within the earth's orbit, and the superior ones without it?—10. Explain Fig. 1, and show why the inferior planets never can be in opposition to the sun.—11. What are the shapes of the planetary orbits? What is meant by perihelion? What is meant by aphelion?

always in the lower foci of their orbits. The orbit of a planet is represented by Fig. 2, where A, D, B, E, is an ellipse, with its two foci, S and O, the sun being in the focus S, which is called the lower focus. When the Earth, or any other planet, revolving around the sun, is in that part of its orbit nearest the sun, as at A, it is said to be in its *perihelion;* and when in that part which is at the greatest distance from the sun, as at B, it is said to be in its *aphelion.* The line, S D, is the mean, or average distance of a planet's orbit from the sun.

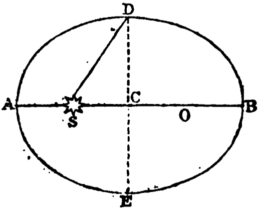

Fig. 2.

12. *Ecliptic.*—"The *planes* of the orbits of all the planets pass through the centre of the sun. The plane of an orbit is an imaginary surface, passing from one extremity, or side, of the orbit, to the other. If the rim of a drum-head be considered the orbit, its plane would be the parchment extended across it, on which the drum is beaten. Let us suppose the earth's orbit to be such a plane, cutting the sun through his centre, and extending out on every side to the starry heavens; the great circle so made, would mark the line of the *ecliptic*, or the sun's apparent path through the heavens. This circle is called the sun's *apparent* path, because the revolution of the earth gives the sun the appearance of passing through it. It is called the ecliptic, because eclipses happen when the moon is in, or near, this apparent path.

13. *Zodiac.*—"The zodiac is an imaginary belt, or broad circle, extending quite around the heavens. The ecliptic divides the zodiac into two equal parts, the zodiac extending 8 degrees on each side of the ecliptic, and being therefore 16 degrees wide. The zodiac is divided into 12 equal parts, called the *signs of the zodiac.*

14. "The sun appears every year to pass around the great circle of the ecliptic, and consequently, through the 12

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12. What is the plane of an orbit? Explain what is meant by the ecliptic. Why is the ecliptic called the sun's apparent path? 13. What is the zodiac? How does the ecliptic divide the zodiac? How far does the zodiac extend on each side of the ecliptic?—14. Explain *Fig. 3, and show why the* sun seems to pass through the ecliptic, when *the earth only revolves* around the sun.

constellations, or signs of the zodiac. But it will be seen, in another place, that the sun, in respect to the earth, stands still, and that his apparent yearly course through the heavens is caused by the annual revolution of the earth around its orbit. To understand the cause of this deception, let us suppose that S, Fig. 3, is the sun, A B, a part of the circle of the ecliptic, and C D, a part of the earth's orbit. Now, if a spectator be placed at C, he will see the sun in that part of the ecliptic marked by B, but when the earth moves in her annual revolution to D, the spectator will see the sun in that part of the heavens marked by A; so that the motion of the earth in one direction, will give the sun an apparent motion in the contrary direction.

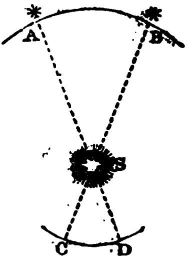

Fig. 3.

15. "A sign, or *constellation*, is a collection of fixed stars, and, as we have already seen, the sun appears to move through the twelve signs of the zodiac every year. Now, the sun's place in the heavens, or zodiac, is found by his apparent conjunction, or nearness to any particular star in the constellation. Suppose a spectator at C, observes the sun to be nearly in a line with the star at B, then the sun would be near a particular star in a certain constellation. When the earth moves to D, the sun's place would assume another direction, and he would seem to have moved into another constellation, and near the star A.

16. "Each of the 12 signs of the zodiac is divided into 30 smaller parts, called *degrees;* each degree into 60 equal parts, called *minutes*, and each minute into 60 parts, called *seconds*.

17. "The division of the zodiac into *signs*, is of very ancient date, each sign having also received the name of some animal, or object, which the constellation, forming that sign, was supposed to resemble. It is hardly necessary to say, that this is chiefly the result of imagination, since the figures

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15. What is a constellation or sign? How is the sun's apparent place in the heavens found?—16. Into how many parts are the signs of the zodiac divided, and what are these parts called?—17. Is there any resemblance between the places of the stars and the figures of the animals after which they are called? Explain why this is a convenient method of finding any *particular star in a sign?*

made by the places of the stars, never mark the outlines of the figures of animals, or other objects. This is, however, found to be the most convenient method of finding any particular star at this day, for among astronomers, any star, in each constellation, may be designated by describing the part of the animal in which it is situated. Thus, by knowing how many stars belong to the constellation Leo, or the Lion, we readily know what star is meant by that which is situated on the Lion's ear or tail."

18. The signs of the zodiac have each a special *name* and *symbol*, and are arranged in a certain order, reckoning from west to east, called the *order of the signs*. These are—♈ Aries. ♉ Taurus. ♊ Gemini. ♋ Cancer. ♌ Leo. ♍ Virgo. ♎ Libra. ♏ Scorpio. ♐ Sagittarius. ♑ Capricornus. ♒ Aquarius. ♓ Pisces. It has been decided by the Egyptian Institute that these names are derived from comparisons made by the Egyptians between celestial and terrestrial phenomena, being principally of a local nature, and belonging exclusively to a part of their own country. Thus,

1. *Capricornus.*—The first month of summer, extending from June 20 to July 20. He begins the year, and leads the celestial animals, as the goat is the leader of the flock.
2. *Aquarius.*—The second month of summer, when the inundation of the Nile is at its full extent.
3. *Pisces.* The third month of summer, when the rise of the waters cause the fish to move about.
4. *Aries.* The first month of autumn, extending from September 20 to October 20. As the waters subside, the ram returns to the pastures, leading the flocks which have been held captive by the inundation.
5. *Taurus.* The second month of autumn, denoting the period of tillage in Egypt.
6. *Gemini.* The third month of autumn, when the seeds germinate. The sign is that of two youths of different sexes.
7. *Cancer.* The first month of winter, extending from Dec. 20 to Jan. 20. The motion of the crab indicates the retrograde motion of the sun at the winter solstice.
8. *Leo.* The second month of winter. The king of animals typifies the strength and grandeur of nature at this period.

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18. What are the names of the twelve signs?

9. *Virgo.* The third month of winter. The sign denotes beauty and fruitfulness.
10. *Libra.* The first month of spring, extending from March 20 to April 20. Allusion is made to the vernal equinox, when the days and nights are equal.
11. *Scorpio.* The second month of spring, when the heat stimulates venomous reptiles, and induces disease and pestilence.
12. *Sagittarius.* The last month of spring. The centaur drives all before him; its course is drawing to a close. —*Arago.*

19. "The twelve signs of the zodiac, together with the sun, and the earth revolving around him, are represented at

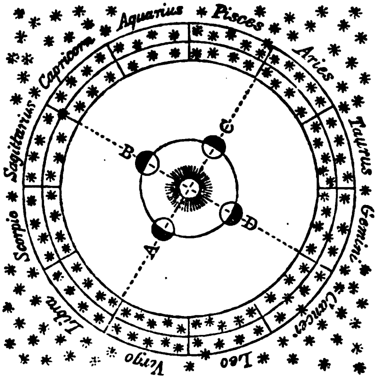

Fig. 4.

Fig. 4. When the earth is at A, the sun will appear to be just entering the sign Aries, because then, when seen from the earth, he ranges towards certain stars at the beginning of that constellation. When the earth is at C, the sun will appear in the opposite part of the heavens, and therefore in the beginning of Libra. The middle line, dividing the circle of the zodiac into equal parts, is the line of the ecliptic.

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19. *Explain why the sun will be in the beginning of Aries, when the earth is at* A, *Fig.* 4.

20. *Density of the planets.*—"Astronomers have no means of ascertaining whether the planets are composed of the same kind of matter as our earth, or whether their surfaces are clothed with vegetables and forests, or not. They have, however, been able to ascertain the densities of several of them by observations on their mutual attraction. By density is meant compactness, or the quantity of matter in a given space. When two bodies are of equal bulk, that which weighs the more has the greater density. It is also well known that substances attract each other in proportion to the quantities of matter they contain. If, therefore, we know the dimensions of several bodies, and can ascertain the proportion in which they attract each other, their quantities of matter or densities are easily found.

21. "Thus, when the planets pass each other in their circuits through the heavens, they are often drawn a little out of the lines of their orbits by mutual attraction. As bodies attract in proportion to their quantities of matter, it is obvious that the small planets, if of the same density, will suffer greater disturbance from this cause than the large ones. But suppose two planets, of the same dimensions, pass each other, and it is found that one of them is attracted twice as far out of its orbit as the other, then, by the known laws of gravity, it would be inferred that one of them contained twice the quantity of matter that the other did, and therefore that the density of the one was twice that of the other. By calculations of this kind, it has been found that the density of the sun is but a little greater than that of water, while Mercury is more than nine times as dense as water, having a specific gravity nearly equal to that of lead. The earth has a density about five times greater than that of the sun, and a little less than half that of Mercury. The densities of the other planets seem to diminish in proportion as their distances from the sun increase, the density of Saturn, one of the most remote of the planets, being only about one-third that of water."

22. All the heavenly bodies are *spheres*, or approach nearly

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20. What is meant by density? In what proportion do bodies attract each other?—21. How are the densities of the planets ascertained? What is the density of the sun, of Mercury, and of the earth? In what proportions do the densities of the planets appear to diminish?—22. *What is a sphere?* Why is the spherical form of the heavenly bodies *imperceptible?* What is a hemisphere?

to the figure of a sphere. The term sphere, in geometry, denotes a solid body, described by the revolution of a semicircle about its diameter; or it may be defined to be a body bounded by a surface of which every point is equally distant from a single point within the surface, called the centre of the sphere. The spherical form of the heavenly bodies is, however, not obvious to our sight, in consequence of their enlightened parts only being seen by us, and that at a considerable distance; hence they appear to us as plane surfaces, which are usually termed *discs*. The projection of a spherical body is always that of a circular plane. A map is nothing more than a representation, upon a plane, of some portion of the surface of a sphere. A *hemisphere* is a half-sphere, produced by cutting a sphere through the centre by a right line in any direction: thus, in reference to the earth, we speak of a northern and a southern hemisphere, an eastern and a western hemisphere, an upper and a lower hemisphere.*

THE SUN.

23. "The sun is the centre of the solar system, and the great dispenser of heat and light to all the planets. Around the sun all the planets revolve, as around a common centre, he being the largest body in our system, and, so far as we know, the largest in the universe.

24. "The distance of the sun from the earth is 95 millions of miles, and his diameter is estimated at 880,000 miles. Our globe, when compared with the magnitude of the sun, is a mere point, for his bulk is about *thirteen hundred thousand times* greater than that of the earth. Were the sun's centre placed in the centre of the moon's orbit, his circumference would reach two hundred thousand miles beyond her orbit in every direction, thus filling the whole space between us and the moon, and extending nearly as far beyond her as she is

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23. Where is the place of the sun in the solar system?—24. What is the distance of the sun from the earth? What is the sun's diameter?

* "When the continents and seas are laid down on a globe, (and, since the discovery of Australia, we are sure that no very extensive tracts of land remain unknown, except perhaps at the south pole), we find that it is possible so to divide the globe into two hemispheres, that one shall contain *nearly all the land*, the other being almost entirely sea. It is a fact, not a little interesting to Englishmen, and, combined with our insular station in that great highway of nations, the Atlantic, not a little explanatory of our commercial eminence, that *London occupies* nearly the centre of the terrestrial hemisphere."—Herschel, *p. 154.*

from us. A traveller, who should go at the rate of 90 miles a day, would perform a journey of nearly 33,000 miles in a year, and yet it would take such a traveller more than 80 years to go round the circumference of the sun. A body of such mighty dimensions, hanging on nothing, it is certain, must have emanated from an Almighty power.

25. "The sun appears to move around the earth every 24 hours, rising in the east, and setting in the west. This motion, as will be proved hereafter, is only apparent, and arises from the diurnal revolution of the earth on its own axis. The sun, although he does not, like the planets, revolve in an orbit, is, however, not without motion, having a revolution around his own axis once in 25 days and 10 hours. Both the fact that he has such a motion, and the time in which it is performed, have been ascertained by the spots, or *faculæ*, on his surface. If a spot is seen, on a revolving body, in a certain direction, it is obvious, that when the same spot is again seen, in the same direction, the body has made one revolution. By such spots the diurnal revolutions of the planets, as well as that of the sun, have been determined.

26. "Spots on the sun seem first to have been observed in the year 1611, since which time they have constantly attracted attention, and have been the subject of investigation among astronomers. These spots change their appearance as the sun revolves on his axis, and become greater or less, to an observer on the earth, as they are turned to, or from him; they also change in respect to real magnitude and number: one spot, seen by Dr Herschel, was estimated to be more than six times the size of our earth, being 50,000 miles in diameter. Sometimes forty or fifty spots may be seen at the same time, and sometimes only one. They are often so large as to be seen with the naked eye; this was the case in 1816.

27. "In respect to the nature and design of these spots, almost every astronomer has formed a different theory. Some have supposed them to be solid opaque masses of

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25. What is the apparent motion of the sun? How is this apparent motion explained? How is it proved that the sun revolves on his own axis? How often does the sun revolve?—26. When were spots of the sun first observed? What has been the difference in the number of spots observed? What was the size of the spot seen by Dr Herschel?—27. What has been advanced concerning the nature of these spots? Have they been accounted for satisfactorily?

scoriæ, floating in the liquid fire of the sun; others, as satellites, revolving round him, and hiding his light from us; others, as immense masses, which have fallen on his disc, and which are dark coloured, because they have not yet become sufficiently heated. In two instances, these spots have been seen to burst into several parts, and the parts to fly in several directions, like a piece of ice thrown upon the ground. Others have supposed that these dark spots were the body of the sun, which became visible in consequence of openings through the fiery matter, with which he is surrounded. Dr Herschel, from many observations with his great telescope, concludes, that the shining matter of the sun consists of a mass of phosphoric clouds, and that the spots on his surface are owing to disturbances in the equilibrium of this luminous matter, by which openings are made through it. There are, however, objections to this theory, as indeed there are to all the others, and at present it can only be said, that no satisfactory explanation of the cause of these spots has been given.

28. "That the sun, at the same time that he is the great source of heat and light to all the solar worlds, may yet be capable of supporting animal life, has been the favourite doctrine of several able astronomers. Dr Wilson first suggested that this might be the case, and Dr Herschel, with his telescope, made observations which confirmed him in this opinion. The latter astronomer supposed that the functions of the sun, as the dispenser of light and heat, might be performed by a luminous, or phosphoric atmosphere, surrounding him at many hundred miles distance, while his solid nucleus might be fitted for the habitations of millions of reasonable beings. This doctrine is, however, rejected by most writers on the subject at the present day." M. Arago inclines to the opinion that the sun consists of an obscure and solid nucleus, enveloped by two atmospheres,—the one obscure, the other luminous. According to this view, the appearance of the spots is explained by ruptures occurring in the atmosphere, and exposing the globe of the sun to view. The penumbra, by which the spots are commonly surrounded, is the extremity of the inner and dark atmosphere, the rent in which is not so wide as that in the luminous one, and which is seen round the opening which exposes the central nucleus.

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28. What is said concerning the sun's being a habitable globe?

MERCURY.

29. "*Mercury*, the planet nearest the sun, is about miles in diameter, and revolves around him at the dis of 37 millions of miles. The period of his annual re tion is 87 days, and he turns on his axis once in abo hours.

30. "No signs of an atmosphere have been observ this planet. The sun's heat at Mercury is about seven greater than it is on the earth, so that water, if natur lows the same laws there that she does here, cannot ex Mercury, except in the state of steam.

31. "The nearness of this planet to the sun, and the time his fully illuminated disc is turned towards the prevent his being often seen. He may, however, some be observed just before the rising, and a little after th ting of the sun. When seen after sunset, he appe brilliant, twinkling star, showing a white light, which, ever, is much obscured by the glare of twilight. Wher in the morning, before the rising of the sun, his light i obscured by the sun's rays.

32. "Mercury sometimes crosses the disc of the su comes between the earth and that luminary, so as to a like a small dark spot passing over the sun's face. T called the *transit* of Mercury.

VENUS.

33. "*Venus* is the other planet whose orbit is v that of the earth. Her diameter is about 8600 miles, somewhat larger than the earth. Her revolution aroun sun is performed in 224 days, at the distance of 68 mi of miles from him. She turns on her axis once in 23 h so that her day is a little shorter than ours.

34. "Venus, as seen from the earth, is the most bri of all the primary planets, and is better known tha

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29. What is the diameter of Mercury, and what are his periods of and diurnal revolution?—30. How great is the sun's heat at Me —31. At what times is Mercury to be seen?—32. What is a of Mercury?—33. Where is the orbit of Venus in respect to that earth? What is the time of Venus's revolution round the sun? *often* does she turn on her axis?—34. What is said of the height *mountains in Venus?* On what account are the transits of Ve *served with great care?*

nocturnal luminary except the moon. When seen through a telescope, she exhibits the phases or horned appearance of the moon, and her face is sometimes variegated with dark spots. Venus may often be seen in the day time, even when she is in the vicinity of the blazing light of the sun. A luminous appearance around this planet, seen at certain times, proves that she has an atmosphere. Some of her mountains are several times more elevated than any on our globe, being from 10 to 22 miles high. Venus sometimes makes a transit across the sun's disc, in the same manner as Mercury, already described. The transits of Venus occur only at distant periods from each other. The last transit was in 1769, and the next will not happen until 1874. These transits have been observed by astronomers with the greatest care and accuracy, since it is by observations on them that the true distances of the earth and planets from the sun are determined.

35. "When Venus is in that part of her orbit which gives her the appearance of being west of the sun, she rises before him, and is then called the *morning* star; and when she appears east of the sun, she is behind him in her course, and is then called the *evening* star. These periods do not agree, either with the yearly revolution of the earth, or of Venus, for she is alternately 290 days the morning star, and 290 days the evening star. The reason of this is, that the earth and Venus move round the sun in the same direction, and hence her relative motion, in respect to the earth, is much slower than her absolute motion in her orbit. If the earth had no yearly motion, Venus would be the morning star one-half of the year, and the evening star the other half.

THE EARTH.

36. "The next planet in our system, nearest the sun, is the earth. Her diameter is 7912 miles. This planet revolves around him in 365 days, 5 hours, and 48 minutes; and at the distance of 95 millions of miles. She turns round her own axis once in 24 hours, making a day and a night. The earth's revolution around the sun is called her *annual*,

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35. When is Venus the morning, and when the evening star? How long is Venus the morning, and how long the evening star?—36. How long does it take the earth to revolve round the sun? What is meant *by the earth's* annual revolution, and what by her diurnal revolution?

or *yearly* motion, because it is performed in a year; while the revolution around her own axis, is called the *diurnal* or daily motion, because it takes place every day. The figure of the earth, with the phenomena connected with her motion, will be explained in another place.

THE MOON.

37. "The moon, next to the sun, is, to us, the most brilliant and interesting of all the celestial bodies. Being the nearest to us of any of the heavenly orbs, and apparently designed for our use, she has been observed with great attention, and many of the phenomena which she presents, are therefore better understood and explained, than those of the other planets.

38. "While the earth revolves round the sun in a year, it is attended by the moon, which makes a revolution round the earth once in 27 days, 7 hours, and 43 minutes. The distance of the moon from the earth is 240,000 miles, and her diameter about 2000 miles. Her surface, when seen through a telescope, appears diversified with hills, mountains, valleys, rocks, and plains, presenting a most interesting and curious aspect; but the explanation of these phenomena are reserved for another section.

MARS.

39. "The next planet in the solar system is Mars, his orbit surrounding that of the earth. The diameter of this planet is upwards of 4000 miles, being about half that of the earth. The revolution of Mars around the sun is performed in nearly 687 days, or in somewhat less than two of our years, and he turns on his axis once in 24 hours and 40 minutes. His mean distance from the sun is 144 millions of miles, so that he moves in his orbit at the rate of about 55,000 miles in an hour. The days and nights, at this planet, and the different seasons of the year, bear a considerable resemblance to those of the earth. The density of Mars is less than that of the earth, being only three times that of water.

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37. Why are the phenomena of the moon better explained than those of the other planets?—38. In what time is a revolution of the moon about the earth performed? What is the distance of the moon from the earth?—39. What is the diameter of Mars? How much longer is a year at Mars than our year? What is his rate of motion in his orbit?

40. "Mars reflects a dull red light, by which he may be distinguished from the other planets. His appearance through the telescope is remarkable for the great number and variety of spots which his surface presents. Mars has an atmosphere of great density and extent, as is proved by the dim appearance of the fixed stars when seen through him. When any of the stars are seen nearly in a line with this planet, they give a faint, obscure light, and the nearer they approach the line of his disc, the fainter is their light, until the star is entirely obscured from the sight. The sun's heat at this planet is less than half that which we enjoy.

41. "This planet sometimes appears much larger to us than at others, and this is readily accounted for by his greater or less distance. At his nearest approach to the earth, his distance is only fifty millions of miles, while his greatest distance is 240 millions of miles; making a difference in his distance of 190 millions of miles, or the diameter of the earth's orbit.

42. "To the inhabitants of Mars, our planet appears alternately as the morning and evening star, as Venus does to us, and as Mercury does to Venus.

VESTA, JUNO, PALLAS, AND CERES.

43. "These planets were unknown until recently, and are therefore sometimes called the *new* planets. They are the smallest of all the planets, and have therefore been called *Asteroids*.

44. "The orbit of *Vesta* is next in the solar system to that of Mars. This planet was discovered by Dr Olbers, of Bremen, in 1807. The light of Vesta is of a pure white, and in a clear night she may be seen with the naked eye, appearing about the size of a star of the 5th or 6th magnitude, Her revolution round the sun is performed in 3 years and 66 days, at the distance of 223 millions of miles from him.

45. "*Juno* was discovered by Mr Harding of Bremen, in 1804. Her mean distance from the sun is 253 millions of

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40. What is his appearance through the telescope? How is it proved that Mars has an atmosphere of great density? How great is the sun's heat at Mars?—41. Why does Mars sometimes appear to us larger than at others?—43. Which are the new planets, or asteroids?—44. When was Vesta discovered? What is the period of Vesta's annual revolution?—45. When was Juno discovered? What is her distance from the sun? What is the period of her revolution, and what her diameter?

miles. Her orbit is more elliptical than that of any other planet, and, in consequence, she is sometimes 127 millions of miles nearer the sun than at others. This planet completes its annual revolution in 4 years and about 4 months, and revolves round its axis in 27 hours. Its diameter is 1400 miles.

46. "*Pallas* was also discovered by Dr Olbers, in 1802. Her distance from the sun is 226 millions of miles, and her periodic revolution round him is performed in 4 years and 7 months.

47. "*Ceres* was discovered in 1801, by Piazzi, of Palermo. This planet performs her revolution in the same time as Pallas, being 4 years and 7 months. Her distance from the sun is 260 millions of miles. According to Dr Herschel, this planet is only about 160 miles in diameter.

JUPITER.

48. "Jupiter is 89,000 miles in diameter, and performs his annual revolution once in about 11 years, at the distance of 490 millions of miles from the sun. This is the largest planet in the solar system, being about 1400 times larger than the earth. His diurnal revolution is performed in nine hours and fifty-five minutes, giving his surface, at the equator, a motion of 28,000 miles per hour. This motion is about twenty times more rapid than that of our earth at the equator

49. "Jupiter, next to Venus, is the most brilliant of the planets, though the light and heat of the sun on him are nearly 25 times less than on the earth.

50. "This planet is distinguished from all the others, by an appearance resembling bands, which extend across his disc. These are termed *belts*, and are variable, both in respect to number and appearance. Sometimes seven or eight are seen, several of which extend quite across his face, while others appear broken, or interrupted. These bands, or belts, when the planet is observed through a telescope, appear as repre-

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46, 47. What is said of Pallas and Ceres? 48. What is the diameter of Jupiter? What is his distance from the sun? What is the period of Jupiter's diurnal revolution?—49. What are the sun's heat and light at Jupiter, when compared with that of the earth?—50. For what is Jupiter particularly distinguished? Is the appearance of Jupiter's belts always the same, or do they change?

sented in Fig. 5. This appearance is much the most common, the belts running quite across the face of the planet in parallel lines. Sometimes, however, his aspect is quite different from this, for in 1780, Dr Herschel saw the whole disc of Jupiter covered with small curved lines, each of which appeared broken, or interrupted, the whole having a parallel direction across his disc, as in Fig. 6.

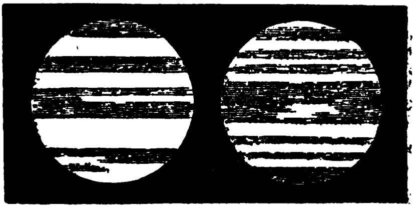

Fig. 5.

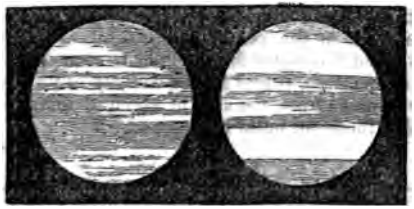

Fig. 6.

51. "Different opinions have been advanced by astronomers respecting the cause of these appearances. By some they have been regarded as clouds, or as openings in the atmosphere of the planet, while others imagine that they are the marks of great natural changes, or revolutions, which are perpetually agitating the surface of that planet. It is, however, most probable, that these appearances are produced by the agency of some cause, of which we, on this little earth, must always be entirely ignorant.

52. "Jupiter has four satellites, or moons; two of which are sometimes seen with the naked eye. They move round,

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51. What is said of the cause of Jupiter's belted appearance?—52. How many moons has Jupiter, and what are the periods of their revolutions?

and attend him in his yearly revolution, as the moon does our earth. They complete their revolutions at different periods, the shortest of which is less than two days, and the longest seventeen days.

53. "These satellites often fall into the shadow of their primary, in consequence of which they are eclipsed, as seen from the earth. The eclipses of Jupiter's moons have been observed with great care by astronomers, because they have been the means of determining the exact longitude of places, and the velocity with which light moves through space. How longitude is determined by these eclipses, cannot be explained or understood at this place, but the method by which they become the means of ascertaining the velocity of light, may be readily comprehended. An eclipse of one of these satellites appears, by calculation, to take place sixteen minutes sooner, when the earth is in that part of her orbit nearest to Jupiter, than it does when the earth is in that part of her orbit at the greatest distance from him. Hence, light is found to be sixteen minutes in crossing the earth's orbit, and as the sun is in the centre of this orbit, or nearly so, it must take about 8 minutes for the light to come from him to us. Light, therefore, passes at the velocity of 95 millions of miles, our distance from the sun, in about 8 minutes, which is nearly 200 thousand miles in a second.

SATURN.

54. "The planet Saturn revolves round the sun in a period of about 30 of our years, and at the distance from him of 900 millions of miles. His diameter is 79,000 miles, making his bulk nearly nine hundred times greater than that of the earth; but notwithstanding this vast size, he revolves on his axis once in about ten hours. Saturn, therefore, performs upwards of 25,000 diurnal revolutions in one of his years, and hence his year consists of more than 25,000 days; a period of time equal to more than 10,000 of our days. On account of the remote distance of Saturn from the sun, he

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53. What occasions the eclipses of Jupiter's moons? Of what use are these eclipses to astronomers? How is the velocity of light ascertained by the eclipses of Jupiter's satellites?—54. What is the time of Saturn's periodic revolution round the sun? What is his distance from the sun? *What his diameter?* What is the period of his diurnal revolution? *How many days* make a year at Saturn? How many moons has Saturn?

receives only about a 90th part of the heat and light which we enjoy on the earth. But to compensate, in some degree, for this vast distance from the sun, Saturn has seven moons, which revolve round him at different distances, and at various periods, from 1 to 80 days.

55. "Saturn is distinguished from the other planets by his *ring*, as Jupiter is by his belt. When this planet is viewed through a telescope, he appears surrounded by an immense luminous circle, which is represented by Fig. 7. There are indeed two luminous circles, or rings, one within the other, with a dark space between them, so that they do not appear to touch each other. Neither does the inner ring touch the body of the planet, there being, by estimation, about the distance of thirty thousand miles between them. The external circumference of the outer ring is 640,000 miles, and its breadth from the outer to the inner circumference, 7,200 miles, or nearly the diameter of our earth. The dark space between the two rings, or the interval between the inner and the outer ring, is 2,800 miles. This immense appendage revolves round the sun with the planet,—performs daily revolutions with it, and, according to Dr Herschel, is a solid substance, equal in density to the body of the planet itself.

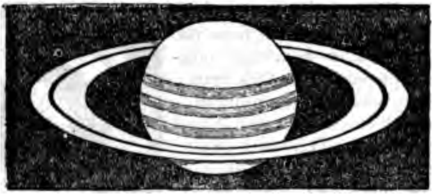

Fig. 7.

56. "The design of Saturn's ring, an appendage so vast, and so different from any thing presented by the other planets, has always been a matter of speculation and inquiry among astronomers. One of its most obvious uses appears to be that of reflecting the light of the sun on the body of the planet, and possibly it may reflect the heat also, so as in some degree to soften the rigour of so inhospitable a climate.

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55. How is Saturn particularly distinguished from all the other planets? What distance is there between the body of Saturn and his inner ring? What distance is there between his inner and outer ring? What is the circumference of the outer ring?

57. "As this planet revolves around the sun, one of its sides is illuminated during one half of the year, and the other side during the other half; so that, as Saturn's year is equal to thirty of our years, one of his sides will be enlightened and darkened, alternately, every fifteen years, as the poles of our earth are alternately in the light and dark every year.

58. "Fig. 8 represents Saturn as seen by an eye placed at right angles to the plane of his ring. When seen from the earth, his position is always oblique, as represented by this figure. The inner white circle represents the body of the planet, enlightened by the sun. The dark circle, next to this, is the unenlightened space between the body of the planet and the inner ring, being the dark expanse of the heavens beyond the planet. The two white circles are the rings of the planet, with the dark space between them, which also is the dark expanse of the heavens.

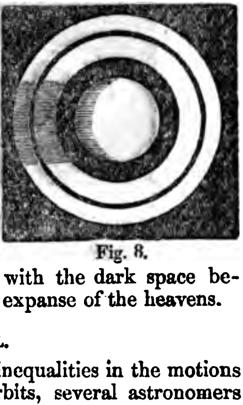

Fig. 8.

HERSCHEL.

59. "In consequence of some inequalities in the motions of Jupiter and Saturn, in their orbits, several astronomers had suspected that there existed another planet beyond the orbit of Saturn, by whose attractive influence these irregularities were produced. The conjecture was confirmed by Dr Herschel, in 1781, who in that year discovered the planet which is now generally known by the name of its discoverer, though called by him *Georgium sidus.* The orbit of Herschel is beyond that of Saturn, and at the distance of 1800 millions of miles from the sun. To the naked eye this planet appears like a star of the sixth magnitude, being, with the exception of some of the comets, the most remote body, so far as is known, in the solar system.

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57. How long is one of Saturn's sides alternately in the light and dark?—58. In what position is Saturn represented in Fig. 8?—59. What circumstance led to the discovery of Herschel? In what year, and by whom, was Herschel discovered? What is the distance of Herschel *from the sun?*

60. "Herschel completes his revolution round the sun in nearly 84 of our years, moving in his orbit at the rate of 15,000 miles in an hour. His diameter is 35,000 miles, so that his bulk is about eighty times that of the earth. The light and heat of the sun at Herschel is about 360 times less than it is at the earth, and yet it has been found, by calculation, that this light is equal to 248 of our full moons, a striking proof of the inconceivable quantity of light emitted by the sun.

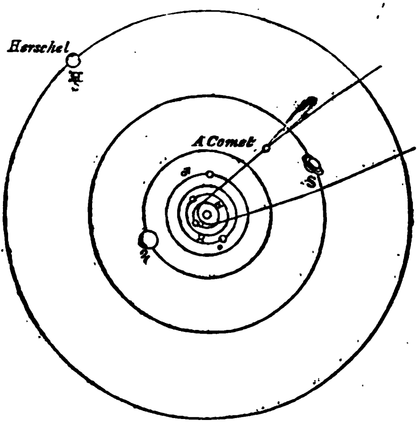

Fig. 9.

61. "This planet has six satellites, which revolve round him at various distances, and in different times. The periods of some of these have been ascertained, while those of the others remain unknown.

62. "*Relative situations of the planets.*—Having now given a short account of each planet composing the solar system, the relative situations of their several orbits, with the exception of those of the Asteroids, are shown by Fig. 9, in which the orbits are marked by the signs of each planet, of which the first, or that nearest the sun, is Mercury, the next Venus,

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60. In what period is his revolution round the sun performed? What is the diameter of Herschel? What is the *quantity of light and heat at* Herschel, when compared with those of the earth?—61. *How many satellites* has Herschel?

the third the Earth, the fourth Mars; then come those of the Asteroids, then Jupiter, then Saturn, and lastly Herschel.

63. "*Comparative dimensions of the planets.*—The comparative dimensions of the planets are delineated at Fig. 10.

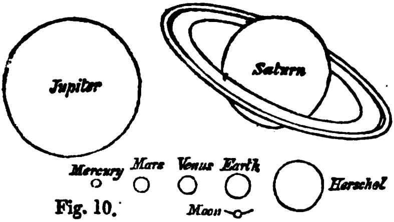

Fig. 10.

PARALLAX.

64. When the position of a heavenly body is observed from different parts of the earth's surface, it is by no means referred to the same point in the heavens: the *apparent* position of the luminary changes with the actual position of the observer. This difficulty does not occur in the case of the fixed stars, which are placed at such infinite distances from our globe, that the visual rays, proceeding from any individual star to different parts of the earth, may be considered parallel. This supposition cannot, however, be made with respect to those bodies which compose the solar system, since they are very much nearer to us, and are consequently seen in different directions from different points of observation. It is, accordingly, necessary to consider more particularly the effect of this difference of situation, and to find the means of applying the proper correction.

65. The term *parallax* denotes simply a change of place or of aspect. In astronomical language, however, it is restricted to the difference of apparent positions of any celestial object when viewed from a station on the *surface* of the earth, and from its *centre*. The *centre of the earth* is the general station to which all astronomical observations are referred; but as we observe from the surface, a *reduction to the centre* is needed;

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64. Is the position of a heavenly body the same when observed at different points on the earth's surface? Do the fixed stars differ from the planets in this respect?—65. What is the general, and what the *astronomical meaning* of the term parallax? What is the difference *between diurnal and* annual parallax?

and the amount of this reduction is called parallax. In other words, the parallax of a body signifies the difference between its *apparent* place and its *true* place, or that in which it would be seen if the observer were situated at the centre to which the motion is referred. When the point of reference is the centre of the earth itself, the change of aspect is called the *diurnal parallax;* when it is the centre of the earth's orbit, the change is called the *annual* parallax.

66. "*Diurnal parallax.*—The diurnal parallax of a heavenly body will be readily understood by reference to the diagram, Fig. 11. Let C be the centre of the earth, A the place of the observer, Z his zenith, and S a heavenly body. On observing the body from A, it will be seen in the direction A S, making the angle Z A S with the zenith. But if the observer could be placed at C, he would see the body in the direction C S, making the angle Z C S with the zenith. The difference between these two angles Z A S and Z C S is the parallax of S, which, therefore, is equal to the angle A S C. Hence it appears that the parallax of a celestial body is the angle comprised between two lines drawn from the body, the one to the centre of the earth, and the other to a point on its surface. On account of the immense distance of the fixed stars, the diurnal parallax is altogether insensible with regard to them. It may amount to a degree in respect of the moon; but the greatest parallax of the nearest planet does not exceed 30″. It is evident from the inspection of the figure, that, although the distance of the object S remains the same, the angle A S C is not a constant quantity, but is greatest when S is seen in the direction of the horizon A H, and diminishes as the altitude of S increases, until it vanishes altogether at the zenith, where the two lines A S and C S merge into the line C Z.

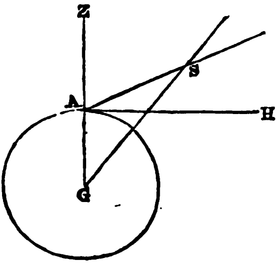

Fig. 11.

67. "*Annual parallax.*—In what has yet been said, the centre of the earth has been taken as the point of reference, and

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66. Explain Fig. 11. What is the greatest parallax of the nearest *planet?*—*67.* What is the parallax of the great orb?

therefore regard has only been had to the difference of apparent situation occasioned by the eccentric position of the observer at the surface of the earth. But the sun, and not the earth, may be regarded as the centre to which the motion is referred, and the position of any celestial body of which the distance from the sun is not so great as to be incomparable with the semidiameter of the earth's orbit, would be different if viewed from the sun, from what it is when viewed from the earth. This difference is called the *annual parallax*, or *parallax of the great orb*. It is the angle under which the semidiameter of the earth's orbit would be seen from a superior planet, or from a fixed star. Such, however, is the enormous distance even of the nearest fixed stars, that, excepting two or three instances, which perhaps may still be regarded as doubtful, not one of them has yet been discovered to be sensibly affected by annual parallax; though observations have been carried to such nicety, that, did the quantity in question amount to a single second, it could not possibly have escaped detection."—*Brande's Dict. of Science, &c.*

MOTIONS OF THE PLANETS.

68. "It is a well known law in physical science, that all undisturbed motion is straight forward, and that a body projected into open space, would continue perpetually to move in a right line, unless retarded or drawn out of this course by some external cause. To account for the motions of the planets in their orbits, we will suppose that the earth, at the time of its creation, was thrown by the hand of the Creator into open space, the sun having been before created and fixed in his present place.

69. "By the term *compound motion*, it is meant, that when a body is acted on by two forces perpendicular to each other, its motion will be in a diagonal line between the direction of the two forces. But we will again here suppose that a ball be moving in the line M X, Fig. 12, with a given force, and that another force

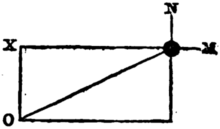

Fig. 12.

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69. Suppose a body to be acted on by two forces perpendicular to each other, *in what direction* will it move? *Why does the ball, Fig. 12, move in a straight line?*

half as great should strike it in the direction of N, the ball would then describe the diagonal of a parallelogram, whose length would be just equal to twice its breadth, and the line of the ball would be straight, because it would obey the impulse and direction of these two forces only.

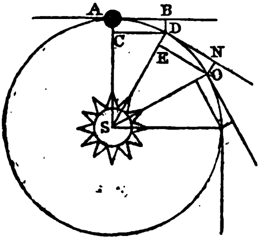

Fig. 13.

70. "Now let A, Fig. 13, represent the earth, and S the sun; and suppose the earth to be moving forward, in the line from A to B, and to have arrived at A, with a velocity sufficient, in a given time, and without disturbance, to carry it to B. But at the point A, the sun, S, acts upon the earth with his attractive power, and with a force which would draw it to C, in the same space of time that it would otherwise have gone to B. Then the earth, instead of passing to B, in a straight line, would be drawn down to D, the diagonal of the parallelogram A, B, D, C. The line of direction, in Fig. 12, is straight, because the body moved obeys only the direction of the two forces; but it is curved from A to D, Fig. 13, in consequence of the continued force of the sun's attraction, which produces a constant deviation from a right line. When the earth arrives at D, still retaining its projectile or centrifugal force, its line of direction would be towards N, but while it would pass along to N without disturbance, the attracting force of the sun is again sufficient to bring it to E, in a straight line, so that, in obedience to the two impulses, it again describes the curve to O.

71. "It must be remembered, in order to account for the circular motions of the planets, that the attractive force of the sun is not exerted at once, or by a single impulse, as is the case with the cross forces, producing a straight line, but that this force is imparted by degrees, and is constant. It therefore acts equally on the earth, in all parts of the course from A to D, and from D to O. From O, the earth, having

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70. Why does the earth, Fig. 13, move in a curved line? Explain Fig. 13, and show how the two forces act to produce a circular line of motion?

the same impulses as before, moves in the same curved or circular direction, and thus its motion is continued perpetually.

72. "The tendency of the earth to move forward in a straight line, is called the *centrifugal force*, and the attraction of the sun, by which it is drawn downwards, or towards a centre, is called its *centripetal force*, and it is by these two forces that the planets are made to perform their constant revolutions around the sun.

73. "In the above explanation, it has been supposed that the sun's attraction, which constitutes the earth's gravity, was at all times equal, or that the earth was at an equal distance from the sun, in all parts of its orbit. But, as heretofore explained, the orbits of all the planets are *elliptical*, the sun being placed in the lower focus of the ellipse. The sun's attraction is, therefore, stronger in some parts of their orbits than in others, and for this reason their velocities are greater at some periods of their revolutions than at others.

74. "To render this intelligible, suppose, as before, that the centrifugal and centripetal forces so balance each other, that the earth moves round the circular orbit A E B, Fig. 14, until it comes to the point E; and at this point, let us suppose that the gravitating force is too strong for the force of projection, so that the earth, instead of continuing its former direction towards B, is attracted by the sun S, in the curve E C. When at C, the line of the earth's projectile force, instead of tending to carry it farther from the sun, as would be the case were it revolving in a circular orbit, now tends to draw it still nearer to him, so that at this point it is impelled by both forces towards the sun. From C, therefore, the force of gravity increasing in proportion as the square of the distance between the sun and earth diminishes, the velocity of the earth will be uniformly accelerated, until it

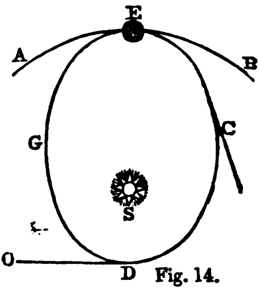

Fig. 14.

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72. What is the projectile force of the earth called? What is the *attractive force of* the sun, which draws the earth towards him, called? *74. Explain Fig.* 14, and show the reason why the velocity is increased *from C to D*, and why it is not retarded from D to G.

arrives at the point nearest the sun, D. At this part of its orbit, the earth will have gained, by its increased velocity, so much centrifugal force, as to give it a tendency to overcome the sun's attraction, and to fly off in the line D O. But the sun's attraction being also increased by the near approach of the earth, the earth is retained in its orbit, notwithstanding its increased centrifugal force, and it therefore passes through the opposite part of its orbit, from D to G, at the same distance from him that it approached. As the earth passes from the sun, the force of gravity tends continually to retard its motion, as it did to increase it while approaching him. But the velocity it had acquired in approaching the sun, gives it the same rate of motion from D to G, that it had from C to D. From G, the earth's motion is uniformly retarded, until it again arrives at E, the point from which it commenced, and from whence it describes the same orbit, by virtue of the same forces, as before. The earth, therefore, in its journey round the sun, moves at very unequal velocities, sometimes being retarded, and then again accelerated, by the sun's attraction.

75. "It is an interesting circumstance, respecting the motions of the planets, that if the contents of their orbits be divided into unequal triangles, the acute angles of which centre at the sun, with the line of the orbit for their bases, the centre of the planet will pass through each of these bases in equal times. This will be understood by Fig. 15, the elliptical circle being supposed to be the earth's orbit, with the sun, S, in one of the foci. Now the spaces 1, 2, 3, &c. though of different shapes, are of the same dimensions, or contain the same quantity of surface. The earth, we have already seen, in its journey round the sun, describes an ellipse, and moves more rapidly in one part of its orbit than in another. But whatever may be its actual velocity, its comparative motion is through equal areas in equal times. Thus its centre passes from E to C, and from

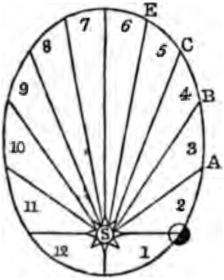

Fig. 15.

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75. What is meant by a planet's passing through equal spaces in equal times?

C to B, in the same period of time, and so of all the other divisions marked in the figure. If the figure, therefore, be considered the plane of the earth's orbit, divided into 12 equal areas, answering to the 12 months of the year, the earth will pass through the same areas in every month, but the spaces through which it passes will be increased, during every month, for one half the year, and diminished, during every month, for the other half.

76. "The reason why the planets, when they approach near the sun, do not fall to him, in consequence of his increased attraction, and why they do not fly off into open space, when they recede to the greatest distance from him, may be thus explained:—

77. "Taking the earth as an example, we have shown that when in the part of her orbit nearest the sun, her velocity is greatly increased by his attraction, and that consequently the earth's centrifugal force is increased in proportion. As an illustration of this, we know that a thread which will sustain an ounce ball, when whirled round in the air, at the rate of 50 revolutions in a minute, would be broken were these revolutions increased to the number of 60 or 70 in a minute, and that the ball would then fly off in a straight line. This shows that when the motion of a revolving body is increased, its centrifugal force is also increased. Now, the velocity of the earth increases in an inverse proportion, as its distance from the sun diminishes, and in proportion to the increase of velocity is its centrifugal force increased; so that, in any other part of its orbit, except when nearest the sun, this increase of velocity would carry the earth away from its centre of attraction. But this increase of the earth's velocity is caused by its near approach to the sun, and consequently the sun's attraction is increased, as well as the earth's velocity. In other terms, when the centrifugal force is increased, the centripetal force is increased in proportion, and thus, while the centrifugal force prevents the earth from falling to the sun, the centripetal force prevents it from moving off in a straight line.

78. "When the earth is in that part of its orbit most dis-

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77. How is it shown, that if the motion of a revolving body is increased, its projectile force is also increased? By what force is the earth's velocity increased as it approaches the sun? When the earth is *nearest the sun*, why does it not fall to him? 78. When the earth's *centrifugal force is greatest*, what prevents its flying to the sun?

tant from the sun, its projectile velocity being retarded by the counter force of the sun's attraction, becomes greatly diminished, and then the centripetal force becomes stronger than the centrifugal, and the earth is again brought back by the sun's attraction, as before, and in this manner its motion goes on without ceasing. It is supposed, as the planets move through spaces void of resistance, that their centrifugal forces remain the same as when they first emanated from the hand of the Creator, and that this force, without the influence of the sun's attraction, would carry them forward into infinite space."

KEPLER'S LAWS.

79. The laws of elliptic motion about the sun as a focus, and of the equable description of areas by lines joining the sun and planets, were originally established by Kepler, from a consideration of the observed motion of Mars; and were by him extended, analogically, to all the other planets. These laws are three:—

1. *That every planet moves so that the line drawn from it to the sun describes about the sun areas proportional to the times.*
2. *That the planets all move in elliptic orbits, of which the sun occupies one of the foci.*
3. *That the squares of the times of the revolutions of the planets are as the cubes of their mean distances from the sun.*

The announcement of these laws by Kepler led to a further inquiry into the causes which governed these movements. 1. From the first law, Newton concluded *that the force acting on the planets is directed towards the centre of the sun.* 2. From the second law, he determined *that the force acting on the planets is in the inverse ratio of the square of the distance of their centres from that of the sun.* 3. From the third law, he found *that the force is proportionate to the mass.*

80. *Kepler's first law.*—"The first law of Kepler gives us no information as to the nature or intensity of the force urging the planets to the sun; the only conclusion it involves, is that it does so urge them. It is a property of orbitual rotation under the influence of central forces *generally*, and, as such, we daily see it exemplified in a thousand familiar instances.

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79. State the three laws of Kepler. What conclusions did Newton draw from these laws?—80. Illustrate the first law of Kepler.

A simple experimental illustration of it, is to tie a bullet to a thin string, and, having whirled it round with a moderate velocity in a vertical plane, to draw the end of the string through a small ring, or allow it to coil itself round the finger or a cylindrical rod held very firmly in a horizontal position. The bullet will then approach the centre of motion in a spiral line; and the increase not only of its angular but of its linear velocity, and the rapid diminution of its periodic time when near the centre, will express, more clearly than any words, the compensation by which its uniform description of areas is maintained under a constantly diminishing distance. If the motion be reversed, and the thread allowed to uncoil, beginning with a rapid impulse, the velocity will diminish by the same degrees as it before increased. The increasing rapidity of a dancer's *pirouette*, as he draws in his limbs and straightens his whole person, so as to bring every part of his frame as near as possible to the axis of his motion, is another instance where the connection of the observed effect with the central force exerted, though equally real, is much less obvious."—*Herschel's Astronomy.*

81. *Kepler's second law.*—"The second law of Kepler involves, as a consequence, the *law* of solar gravitation (so be it allowed to call the force, whatever it be, which urges them towards the sun), as exerted on each individual planet, apart from all connection with the rest. A straight line, dynamically speaking, is the only path which can be pursued by a body *absolutely free*, and under the action of *no* external force. All *deflection* into a curve is evidence of the exertion of a force; and the greater the deflection in equal times, the more intense the force. Deflection from a straight line is only another word for *curvature* of path; and, as a circle is characterized by the uniformity of its curvature in all its parts, so is every other curve (as an ellipse) characterized by the particular *law* which regulates the increase and diminution of its curvature as we advance along its circumference. The deflecting force, then, which continually bends a moving body in a curve, may be ascertained, provided its direction, in the first place, and secondly, the law of curvature of the curve itself, be known. Both these enter as elements into the expression of the force. A body may describe, for instance,

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81. What principle is involved in the second law of Kepler? What *is the cause of* curvature of motion?

an ellipse, under a great variety of dispositions of the acting forces: it may glide along, for example, as a bead upon a polished wire, bent into an elliptic form; in which case the acting force is always perpendicular to the wire, and the velocity is uniform. In this case the *force* is directed to *no fixed* centre, and there is no equable description of areas at all. Or it may describe it as we may see done, if we suspend a ball by a *very* long string, and, drawing it a little aside from the perpendicular, throw it *round* with a gentle impulse. In this case the acting force is directed to the centre of the ellipse, about which areas are described equably, and *to* which a force *proportional* to the distance (the decomposed result of terrestrial gravity) perpetually urges it. This is at once a very easy experiment, and a very instructive one.

82. "In the case before us, of an ellipse described by the action of a force directed to the *focus*, the steps of the investigation of the law of force are these: 1st, The law of the areas determines the actual *velocity* of the revolving body at every point, or the space really run over by it in a given minute portion of time; 2dly, The law of curvature of the ellipse determines the linear amount of deflection from the tangent *in the direction of the focus*, which corresponds to that space so run over; 3dly, and lastly, The laws of accelerated motion declare that the intensity of the acting force causing such deflection *in its own direction*, is measured by, or proportional to, the amount of that deflection, and may therefore be calculated in any particular position, or generally expressed by geometrical or algebraical symbols, *as a law* independent of particular positions, when that deflection is so calculated or expressed. We have here the spirit of the process by which Newton has resolved this interesting problem. For its geometrical detail, we must refer to the third section of his *Principia*. We know of no artificial mode of imitating this species of elliptic motion; though a rude approximation to it—enough, however, to give a conception of the alternate approach and recess of the revolving body to and from the focus, and the variation of its velocity—may be had by suspending a small steel bead to a fine and very long silk fibre, and setting it to revolve in a small orbit round the pole of a powerful cylindrical magnet, held upright, and vertically under the point of suspension."—Ibid.

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82. Can you illustrate the law of elliptic motion?

83. *Kepler's third law.*—"The third law of Kepler, which connects the distances and periods of the planets by a general rule, bears with it, as its theoretical interpretation, this important consequence, viz., that it is one and the same force, modified only by distance from the sun, which retains *all* the planets in their orbits about it. That the attraction of the sun (if such it be) is exerted upon all the bodies of our system indifferently, without regard to the peculiar materials of which they may consist, in the exact proportion of their inertiæ, or quantities of matter; that it is not, therefore, of the nature of the elective attractions of chemistry, or of magnetic action, which is powerless on other substances than iron and some one or two more, but is of a more universal character, and extends equally to all the material constituents of our system, and to those of other systems than our own.

84. "This law, important and general as it is, results, as the simplest of corollaries, from the relations established by Newton in the section of the *Principia* referred to (prop. 15), from which proposition it results, that if the earth were taken from its actual orbit, and launched anew in space at the place, in the direction, and with the velocity of any of the other planets, it would describe the very same orbit, and in the same period, which that planet actually does, a very minute correction of the period only excepted, arising from the difference between the mass of the earth and that of the planet. Small as the planets are compared with the sun, some of them are not, as the earth is, mere atoms in the comparison. The strict wording of Kepler's law, as Newton has proved in his fifty-ninth proposition, is applicable only to the case of planets whose proportion to the central body is absolutely inappreciable. When this is not the case, the periodic time is shortened in the proportion of the square root of the number expressing the sun's mass or inertia, to that of the sum of the numbers expressing the masses of the sun and planet; and in general, whatever be the masses of two bodies revolving round each other under the influence of the Newtonian law of gravity, the square of their periodic time will be expressed by a fraction, whose numerator is the cube of their mean distance, *i. e.* the greater semi-axis of their elliptic orbit, and whose denominator is the sum of their masses.

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83. What important conclusion is deduced from the third law of *Kepler?*

When one of the masses is incomparably greater than the other, this resolves itself into Kepler's law; but when this is not the case, the proposition thus generalized stands in lieu of that law. In the system of the sun and planets, however, the numerical correction, thus introduced into the results of Kepler's law, is too small to be of any importance, the mass of the largest of the planets (Jupiter) being much less than a thousandth part of that of the sun."—*Ibid.*

THE EARTH.

85. "It is almost universally believed in the present day, that the *apparent* daily motion of the heavenly bodies *from east to west*, is caused by the *real* motion of the earth *from west to east*, and yet there are comparatively few who have examined the evidence on which this belief is founded. For this reason, we will here state the most obvious, and to a common observer, the most convincing proofs of the earth's revolution. These are, first, the inconceivable velocity of the heavenly bodies, and particularly of the fixed stars around the earth, if she stands still. Second, the fact, that all astronomers of the present age agree that every phenomenon which the heavens present, can be best accounted for, by supposing the earth to revolve. Third, the analogy to be drawn from many of the other planets, which are known to revolve on their axis; and fourth, the different lengths of days and nights at the different planets, for did the sun revolve about the solar system, the days and nights at many of the planets must be of similar lengths.

86. "The distance of the sun from the earth being 95 millions of miles, the diameter of the earth's orbit is twice its distance from the sun, and therefore 190 millions of miles. Now, the diameter of the earth's orbit, when seen from the nearest fixed star, is a mere point, and were the orbit a solid mass of opaque matter, it could not be seen, with such eyes as ours, from such a distance. This is known by the fact, that these stars appear no larger to us, even when our sight is assisted by the best telescopes, when the earth is in that part of her orbit nearest them, than when at the greatest dis-

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85. What are the most obvious and convincing proofs that the earth revolves on its axis?—86. Were the earth's orbit a solid mass, could it be seen by us at the distance of the fixed stars? Suppose the earth *stood still*, how fast must the sun move to go round it in 24 hours? At *what rate* must the fixed stars move to go round the earth in 24 hours?

tance, or in the opposite part of her orbit. The approach, therefore, of 190 millions of miles towards the fixed stars, is so small a part of their whole distance from us, that it makes no perceptible difference in their appearance. Now, if the earth does not turn on her axis once in 24 hours, these fixed stars must revolve around the earth at this amazing distance once in 24 hours. If the sun passes around the earth in 24 hours, he must travel at the rate of nearly 400,000 miles in a minute; but the fixed stars are at least 400,000 times as far beyond the sun, as the sun is from us, and, therefore, if they revolve around the earth, must go at the rate of 400,000 times 400,000 miles, that is, at the rate of 160,000,000,000, or 160 billions of miles in a minute; a velocity of which we can have no more conception than that of infinity or eternity.

87. "In respect to the analogy to be drawn from the known revolutions of the other planets, and the different lengths of days and nights among them, it is sufficient to state, that to the inhabitants of Jupiter, the heavens appear to make a revolution in about 10 hours, while to those of Venus, they appear to revolve once in 23 hours, and to the inhabitants of the other planets a similar difference seems to take place, depending on the periods of their diurnal revolutions. Now, there is no more reason to suppose that the heavens revolve round us, than there is to suppose that they revolve around any of the other planets, since the same apparent revolution is common to them all; and as we know that the other planets, at least many of them, turn on their axis, and as all the phenomena presented by the earth can be accounted for by such a revolution, it is folly to conclude otherwise.

CIRCLES AND DIVISIONS OF THE EARTH.

88. "It will be necessary for the pupil to retain in his memory the names and directions of the following lines, or circles, by which the earth is divided into parts. These lines, it must be understood, are entirely imaginary, there being no such divisions marked by nature on the earth's surface.

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87. If the heavens appear to revolve every 10 hours at Jupiter, and every 24 hours at the earth, how can this difference be accounted for if they revolve at all? Is there any more reason to believe that the sun *revolves round the earth* than round any of the other planets? How *can all the phenomena* of the heavens be accounted for, if they do not *revolve?*

They are, however, so necessary, that no accurate description of the earth, or of its position with respect to the heavenly bodies, can be conveyed without them.

89. "The earth, whose diameter is 7912 miles, is represented by the globe, or sphere, Fig. 16. The straight line A B passing through its centre, and about which it turns, is called its *axis*, and the two extremities of the axis are the *poles* of the earth, A being the north pole, and B the south pole. The line C D, crossing the axis, passes quite round the earth, and divides it into two equal parts. This is called the *equinoctial line*, or the *equator*. That part of the earth, situated north of this line, is called the *northern hemisphere*, and that part south of it, the *southern hemisphere*. The small circles E F, and G H, surrounding or including the poles, are called the *polar circles;* that surrounding the north pole is called the *arctic circle*, and that surrounding the south, the *antarctic circle*. Between these circles, there is, on each side of the equator, another circle, which marks the extent of the tropics towards the north and south, from the equator. That to the north of the equator, I K, is called the *tropic of Cancer*, and that to the south, L M, the *tropic of Capricorn*. The circle L K, extending obliquely across the two tropics, and crossing the axis of the earth, and the equator, at their point of intersection, is called the *ecliptic*. This circle, as already explained, belongs rather to the heavens than the earth, being an imaginary extension of the plane of the earth's orbit in every direction towards the stars. The line in the figure shows the comparative position or direction of the ecliptic in respect to the equator, and the axis of the earth."

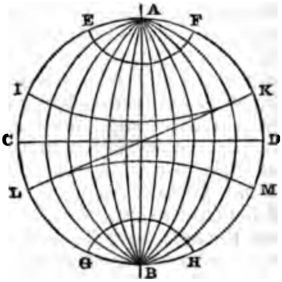

Fig. 16.

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89. **What is the axis of the earth? What are the poles of the earth? What is the equator? Where are the northern and southern hemispheres? What are the polar circles? Which is the arctic, and which the *antarctic circle?* Where is the tropic of Cancer and where the tropic of *Capricorn?* What is the ecliptic?**

90. *Equinoctial line, or equator.*—It has been stated, in the preceding paragraph, that the diameter on which the earth turns is called its axis, the extremities of which are termed its poles. Between these poles, every point in the earth does, by its diurnal rotation, describe a circle; and, because all these circles, however numerous they may be, must always keep at the same distance from the *equator*, or great circle, and run, as it were, by the side of each other, they are hence called *parallels*. The greatest of all these circles, or parallels, is that which occupies the precise middle between the poles. It is called the *equator*, because it divides the globe into two equal parts, as stated above; and *equinoctial* line, because, when the sun is in its plane, *noctes æquantur*, or the day and night are equal over the whole surface of the earth. If this equator ran along exactly under the ecliptic of the heavens, there would *always* be equal day and night over the *whole* world. But the equator *crosses* the ecliptic, as shewn in the figure, and hence the day and night are equal only twice in the year, viz., when the sun appears in one of those two points of the ecliptic where the equator crosses it, viz., in the first point of *aries* and the first of *libra*. These two points are therefore called the *equinoctial points*; and the times of the year corresponding to them are called the *vernal* and the *autumnal equinoxes*, the one occurring in spring, the other in autumn.

91. *The tropics.*—The tropics are those circles on the earth's surface, over which the sun appears to pass directly, when he is at the greatest distance northward and southward from the equator, viz., 23½ degrees in either direction; hence, the one is called the *northern*, the other the *southern tropic*. In the former case, the sun appears to be in the beginning of Cancer; in the latter, in the beginning of Capricorn. The term tropic, derived from the Greek word *tropikos*, denotes a point where a *turn* is made; for the line of the ecliptic quitting the equator in the first point of *aries*, continues to rise higher northward, till it reaches the first point of *cancer*, when it *turns* to the southward; and, after again cutting the equator at the first point of *libra*, continues to descend southward till it reaches the first point of *capricorn*, when

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90. What is meant by parallels? Explain the etymology of the word *equator*. What are the equinoctial points?—91. What are the tropics? To what distance do they extend north and south of the equator?

it again *turns* to the northward, and proceeds again to *aries*.

92. *Solstices.*—The solstices are closely connected with the tropics. The term *solstice* denotes a standing still of the sun. The sun, in fact, *appears* to make a *stand* in the first points of Cancer and Capricorn, going neither northward nor southward; and as these stationary appearances occur in the summer and winter, these two seasons of the year are termed the *summer* and *winter solstices*. Hence the equinoxes and the solstices alternate with each other, in the following order: vernal equinox, summer solstice; autumnal equinox, winter solstice.

93. *Polar circles.*—The north and south polar circles are situated at the same distance from the poles of the earth, as the tropics are from the equator, viz. 23½ degrees. These polar circles bound those portions of the earth where day or night continues during several diurnal revolutions of the earth.

94. "The lines crossing those already described, and meeting at the poles of the earth, are called *meridian lines*, or mid-day lines, for when the sun is on the meridian of a place, it is the middle of the day at that place; and, as these lines extend from north to south, the sun shines on the whole length of each, at the same time, so that it is 12 o'clock, at the same time, on every place situated on the same meridian.

95. "The spaces on the earth, between the lines extending from east to west, are called *zones*. That which lies between the tropics, from M to K, and from I to L, is called the *torrid zone*, because it comprehends the hottest portion of the earth. The spaces which extend from the tropics, north and south, to the polar circles, are called *temperate zones*, because the climates are temperate, and neither scorched with heat, like the tropics, nor chilled with cold, like the frigid zones. That lying north of the tropic of Cancer, is called the *north temperate zone*, and that south of the tropic of Capricorn, the *south temperate zone*. The spaces included within the polar circles, are called the *frigid zones*. The lines which divide the globe into two equal parts, are called

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92. What are the solstices? What does the term signify?—93. What are the polar circles?—94. What are the meridian lines?—95. On what part of the earth is the torrid zone? How are the north and south temperate zones bounded? Where are the frigid zones? Which are the great and which the lesser circles of the earth?

the *great circles;* these are the ecliptic and the equator. Those dividing the earth into smaller parts are called the *lesser circles;* these are the lines dividing the tropics from the temperate zones, and the temperate zones from the frigid zones, &c.

96. "*Horizon:*—The horizon is distinguished into the *sensible* and *rational.* The sensible horizon is that portion of the surface of the earth which bounds our vision, or the circle around us, where the sky seems to meet the earth. When the sun rises, he appears above the sensible horizon, and when he sets, he sinks below it. The rational horizon is an imaginary line passing through the centre of the earth, and dividing it into two equal parts.

97. "*Direction of the ecliptic.*—The ecliptic, we have already seen, is divided into 360 equal parts, called degrees. All circles, however large or small, are divided into degrees, minutes, and seconds, in the same manner as the ecliptic. The *axis* of the ecliptic is an imaginary line passing through its centre and perpendicular to its plane. The extremities of this perpendicular line, are called the *poles* of the ecliptic.

98. "If the ecliptic, or great plane of the earth's orbit, be considered on the horizon, or parallel with it, and the line of the earth's axis be inclined to the axis of this plane, or the axis of the ecliptic, at an angle of 23½ degrees, it will represent the relative positions of the orbit, and the axis of the earth. These positions are, however, merely relative, for if the position of the earth's axis be represented perpendicular to the equator, as A B, Fig. 16, then the ecliptic will cross this plane obliquely, as in that figure. But when the earth's orbit is considered as having no inclination, its axis, of course, will have an inclination, to the axis of the ecliptic, of 23½ degrees.

99. "As the orbits of all the other planets are inclined to the ecliptic, perhaps it is the most natural and convenient method to consider this as a horizontal plane, with the equator inclined to it, instead of considering the equator on the plane of the horizon, as is sometimes done.

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96. What is the difference between the sensible and the rational horizon?—97. What is the axis of the ecliptic? What are the poles of the ecliptic?—98. How many degrees is the axis of the earth inclined to that of the ecliptic? What is said concerning the relative positions *of the earth's axis* and the plane of the ecliptic?—99. Are the orbits *of the other planets* parallel to the earth's orbit, or inclined to it?

100. "*Inclination of the earth's axis.*—The inclination of the earth's axis to the axis of its orbit never varies, but always makes an angle with it of 23½ degrees, as it moves round the sun. The axis of the earth is therefore always parallel with itself: that is, if a line be drawn through the centre of the earth, in the direction of its axis, and extended north and south, beyond the earth's diameter, the line so produced will always be parallel to the same line, or any number of lines, so drawn, when the earth is in different parts of its orbit.

101. "Suppose a rod to be fixed into the flat surface of a table, and so inclined as to make an angle with a perpendicular from the table of 23½ degrees. Let this rod represent the axis of the earth, and the surface of the table, the ecliptic. Now place on the table a lamp, and round the lamp hold a wire circle three or four feet in diameter, so that it shall be parallel with the plane of the table, and as high above it as the flame of the lamp. Having prepared a small terrestrial globe, by passing a wire through it for an axis, and letting it project a few inches each way, for the poles, take hold of the north pole, and carry it round the circle, with the poles constantly parallel to the rod rising above the table. The rod being inclined 23½ degrees from a perpendicular, the poles and axis will be inclined in the same degree, and thus the axis of the earth will be inclined to that of the ecliptic every where in the same degree, and lines drawn in the direction of the earth's axis will be parallel to each other in any part of its orbit.

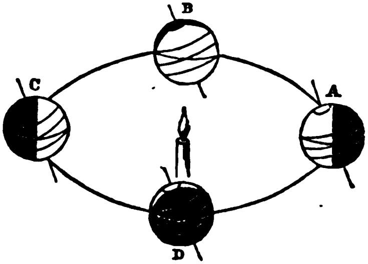

Fig. 17.

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100. What is meant by the earth's axis being parallel to itself?

102. "This will be understood by Fig. 17, where it will be seen, that the poles of the earth, in the several positions of A, B, C, and D, being equally inclined, are parallel to each other. Supposing the lamp to represent the sun, and the wire circle the earth's orbit, the actual position of the earth, during its annual revolution round the sun, will be comprehended; and if the globe be turned on its axis, while passing round the lamp, the diurnal or daily revolution of the earth will also be represented.

DAY AND NIGHT.

103. "Were the direction of the earth's axis perpendicular to the plane of its orbit, the days and nights would be of equal length all the year, for then just one half of the earth, from pole to pole, would be enlightened, and at the same time the other half would be in darkness. Suppose the line S O, Fig. 18, from the sun to the earth, to be the plane of the earth's orbit, and that N S is the axis of the earth perpendicular to it, then it is obvious, that exactly the same points on the earth would constantly pass through the alternate vicissitudes of day and night; for all who live on the meridian line between N and S, which line crosses the equator at O, would see the sun at the same time, and consequently, as the earth revolves, would pass into the dark hemisphere at the same time. Hence in all parts of the globe, the days and nights would be of equal length, at any given place.

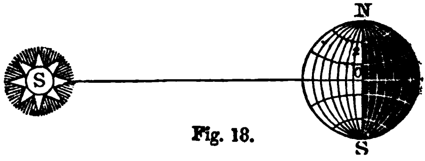

Fig. 18.

104. "Now it is the inclination of the earth's axis, as above described, which causes the lengths of the days and nights to

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102. How does it appear by Fig. 17 that the axis of the earth is parallel to itself in all parts of its orbit? How are the annual and diurnal revolutions of the earth illustrated by Fig. 17.—103. Explain, by Fig. 18, why the days and nights would every where be equal, were the axis of the earth perpendicular to the plane of its orbit?—104. What is the *cause of the unequal lengths* of the days and nights in different parts of *the world?*

differ at the same place at different seasons of the year; for, on reviewing the position of the globe at A, Fig. 17, it will be observed, that the line formed by the enlightened and dark hemispheres, does not coincide with the line of the axis and poles, as in Fig. 18, but that the line formed by the darkness and the light extends obliquely across the line of the earth's axis, so that the north pole is in the light, while the south is in the dark. In the position A, therefore, an observer at the north pole would see the sun constantly, while another at the south pole would not see it at all. Hence those living in the north temperate zone, at the season of the year when the earth is at A, or in the summer, would have long days and short nights, in proportion as they approached the polar circle; while those who live in the south temperate zone, at the same time, and when it would be winter there, would have long nights and short days in the same proportion.

SEASONS OF THE YEAR.

105. "The vicissitudes of the seasons are caused by the annual revolution of the earth around the sun, together with the inclination of its axis to the plane of its orbit. It has already been explained, that the ecliptic is the plane of the earth's orbit, and is supposed to be placed on a level with the earth's horizon, and hence, that this plane is considered the standard, by which the inclination of the lines crossing the earth, and the obliquity of the orbits of the other planets, are to be estimated.

106. "The equinoctial line, or the great circle passing round the middle of the earth, is inclined to the ecliptic, as well as the line of the earth's axis, and hence in passing round the sun, the equinoctial line intersects, or crosses the ecliptic, in two places, opposite to each other. Suppose A B, Fig. 19, to be the ecliptic, E F, the equator, and C D, the earth's axis. The ecliptic and equator are supposed to be

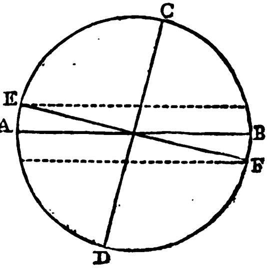

Fig. 19.

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105. What are the causes which produce the seasons of the year?—106. In what position is the equator with respect to the ecliptic?

seen edgewise, so as to appear like lines instead of circles. Now it will be understood from the figure that the inclination of the equator to the ecliptic, (or the sun's apparent annual path through the heavens,) will cause these lines, namely, the line of the equator and the line of the ecliptic, to cut, or cross each other, as the sun makes his apparent annual revolution, and that this intersection will happen twice in the year, when the earth is in the two opposite points of her orbit.

107. "These periods are on the 21st of March, and the 21st of September, in each year, and the points at which the sun is seen at these times, are called the *equinoctial* points. That which happens in September is called the *autumnal* equinox, and that which happens in March, the *vernal* equinox. At these seasons, the sun rises at 6 o'clock and sets at 6 o'clock, and the days and nights are equal in length in every part of the globe.

108. "The solstices are the points where the ecliptic and the equator are at the greatest distance from each other. The earth, in its yearly revolution, passes through each of these

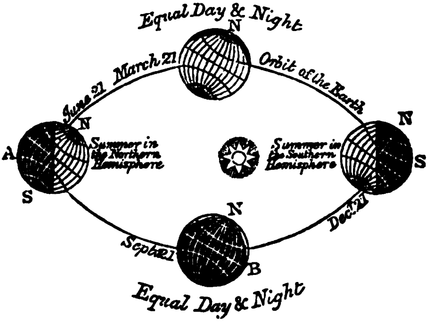

Fig. 20.

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107. At what times in the year does the line of the ecliptic and that of the equinox intersect each other? What are these points of intersection called? Which is the autumnal and which the vernal equinox? At what time does the sun rise and set when he is in the equinoxes?—108. When the sun enters the summer solstice, what is said of the length of the days and nights? When does the sun enter the winter solstice, and what is the proportion between the length of the days and nights?

points. One is called the *summer*, and the other the *winter* solstice. The sun is said to enter the summer solstice on the 21st of June; and at this time, in our hemisphere, the days are longest, and the nights shortest. On the 21st of December, he enters his winter solstice, when the length of the days and nights are reversed from what they were in June before, the days being shortest, and the nights longest.

109. "Having learned these explanations, the student will be able to understand in what order the seasons succeed each other, and the reason why such changes are the effect of the earth's revolution.

110. "Suppose the earth, Fig. 20, to be in her summer solstice, which takes place on the 21st of June. At this period she will be at A, having her north pole, N, so inclined towards the sun, that the whole arctic circle will be illuminated, and consequently the sun's rays will extend 23½ degrees, the breadth of the polar circles, beyond the north pole. The diurnal revolution, therefore, when the earth is at A, causes no succession of day and night at the pole, since the whole frigid zone is within the reach of his rays. The people who live within the arctic circle will, consequently, at this time, enjoy perpetual day. During this period, just the same proportion of the earth that is enlightened in the northern hemisphere, will be in total darkness in the opposite region of the southern hemisphere; so that while the people of the north enjoy perpetual day, those of the south are enveloped in perpetual night. Those who live near the arctic circle in the north temperate zone, will, during the summer, come, for a few hours, within the regions of night, by the earth's diurnal revolution; and the greater the distance from the circle, the longer will be their nights, and the shorter their days. Hence, at this season, the days will be longer than the nights everywhere between the equator and the arctic circle. At the equator, the days and nights will be equal, and between the equator and the south polar circle, the nights will be longer than the days, in the same propor-

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110. At what season of the year is the whole arctic circle illuminated? At what season is the whole antarctic circle in the dark? While the people near the north pole enjoy perpetual day, what is the situation of those near the south pole? At what season will the days be longer than the nights everywhere between the equator and the arctic circle? *At what season* will the nights be longer than the days in the southern *hemisphere?*

tion as the days are longer than the nights, from the equator to the arctic circle.

111. "As the earth moves round the sun, the line which divides the darkness and the light gradually approaches the poles, till having performed one quarter of her yearly journey from the point A, she comes to B, about the 21st of September. At this time, the boundary of light and darkness passes through the poles, dividing the earth equally from east to west; and thus in every part of the world, the days and nights are of equal length, the sun being 12 hours alternately above and below the horizon. In this position of the earth, the sun is said to be in the *autumnal equinox*.

112. "In the progress of the earth from B to S, the light of the sun gradually reaches a little more of the antarctic circle. The days, therefore, in the northern hemisphere, grow shorter at every diurnal revolution, until the 21st of December, when the whole arctic circle is involved in total darkness. And now, the same places which enjoyed constant day in the June before, are involved in perpetual night. At this time, the sun, to those who live in the northern hemisphere, is said to be in his *winter solstice;* and then the winter nights are just as long as were the summer days, and the winter days as long as the summer nights.

113. "When the earth has completed another quarter of her annual journey, and has come to the point of her orbit opposite to where she was on the 21st of September, which happens on the 21st of March, the line dividing the light from the darkness again passes through both poles. In this position of the earth with respect to the sun, the days and nights are again equal all over the world, and the sun is said to be in his *vernal equinox*.

114. "From the vernal equinox, as the earth advances, the northern hemisphere enjoys more and more light, while the southern falls into the region of darkness, in proportion, so that the days north of the equator increase in length, until the 21st of June, at which time the sun is again longest above the horizon, and the shortest time below it.

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111. When will the days and nights be equal in all parts of the earth? —112. At what season of the year is the whole arctic circle involved in *darkness?*—*113. When are the days and nights equal all over the world? When is the sun in the* vernal equinox?

115. "Thus the *apparent* motion of the sun *from east to west*, is caused by the *real* motion of the earth *from west to east*. If the earth is in any point of its orbit, the sun will always seem in the opposite point in the heavens. When the earth moves one degree to the west, the sun seems to move the same distance to the east; and when the earth has completed one revolution in its orbit, the sun appears to have completed a revolution through the heavens. Hence it follows, that the ecliptic, or the apparent path of the sun through the heavens, is the real path of the earth round the sun.

116. "It will be observed by a careful perusal of the above explanation of the seasons, and a close inspection of the figure by which it is illustrated, that the sun constantly shines on a portion of the earth equal to 90 degrees north, and 90 degrees south, from his place in the heavens, and, consequently, that he always enlightens 180 degrees, or one half the earth. If, therefore, the axis of the earth were perpendicular to the plane of its orbit, the days and nights would everywhere be equal, for as the earth performs its diurnal revolutions, there would be 12 hours day, and 12 hours night. But since the inclination of its axis is 23½ degrees, the light of the sun is thrown 23½ degrees beyond the north pole; that is, it enlightens the earth 23½ degrees farther in that direction, when the north pole is turned towards the sun, than it would, had the earth's axis no inclination. Now, as the sun's light reaches only ninety degrees north or south of his place in the heavens, so when the arctic circle is enlightened, the antarctic circle must be in the dark; for if the light reaches 23½ degrees beyond the north pole, it must fall 23½ degrees short of the south pole.

117. "As the earth travels round the sun, in his yearly circuit, this inclination of the poles is alternately *towards* and *from* him. During our winter, the north polar region is thrown beyond the rays of the sun, while a corresponding

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115. What is the cause of the apparent motion of the sun from east to west? What is the apparent path of the sun, but the real path of the earth?—116. Had the earth's axis no inclination, why would the days and nights always be equal? How many degrees does the sun's light reach north and south of him, on the earth?—117. During our winter, is the north pole turned to or from the sun? At the poles, how many days and nights are there in the year? When it is winter in the northern *hemisphere*, what is the season in the southern hemisphere?

portion around the south pole enjoys the sun's light. And thus, at the poles, there are alternately six months of darkness and winter, and six months of sunshine and summer. While we, in the northern hemisphere, are chilled by the cold blasts of winter, the inhabitants of the southern hemisphere are enjoying all the delights of summer; and while we are scorched by the rays of a vertical sun in June and July, our southern neighbours are shivering with the rigours of mid-winter.

118. "At the equator, no such changes take place. The rays of the sun, as the earth passes round him, are vertical twice a year at every place between the tropics. Hence, at the equator, there are two summers and no winter, and as the sun there constantly shines on the same half of the earth in succession, the days and nights are always equal, there being 12 hours of light, and 12 of darkness.

119. "MOTION OF THE EARTH.—The motion of the earth round the sun, is at the rate of 68,000 miles in an hour, while its motion on its own axis, at the equator, is at the rate of about 1042 miles in the hour. The equator, being that part of the earth most distant from its axis, the motion there is more rapid than towards the poles, in proportion to its greater distance from the axis of motion.

120. "The method of ascertaining the velocity of the earth's motion, both in its orbit and round its axis, is simple, and easily understood; for by knowing the diameter of the earth's orbit, its circumference is readily found, and as we know how long it takes the earth to perform her yearly circuit, we have only to calculate what part of her journey she goes through in an hour. By the same principle, the hourly rotation of the earth is as readily ascertained.

121. "We are insensible to these motions, because not only the earth, but the atmosphere, and all terrestrial things, partake of the same motion, and there is no change in the relation of objects in consequence of it. If we look out at the window of a steam-boat, when it is in motion, the boat will seem to stand still, while the trees and rocks on the shore appear to pass rapidly by us. This deception arises from our not having any object with which to compare this motion,

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118. What are the seasons at the equator?—119. At what rate does the earth move around the sun? How fast does it move around its *axis at the equator?*—120. How is the velocity of the earth ascertained? *121. Why are we insensible of the earth's motion?*

when shut up in the boat; for then every object around us keeps the same relative position. And so, in respect to the motion of the earth, having nothing with which to compare its movement, except the heavenly bodies, when the earth moves in one direction, these objects appear to move in the contrary direction.

CAUSES OF THE HEAT AND COLD OF THE SEASONS.

122. "We have seen that the earth revolves round the sun in an elliptical orbit, of which the sun is one of the foci, and consequently, that the earth is nearer to him in one part of her orbit than in another. From the great difference we experience between the heat of summer and that of winter, we should be led to suppose that the earth must be much nearer the sun in the hot season than in the cold. But when we come to inquire into this subject, and to ascertain the distance of the sun at different seasons of the year, we find that the great source of heat and light is nearest us during the cold of winter, and at the greatest distance during the heat of summer.

123. "It is a well known principle in optical science, that the angle of vision depends on the distance at which a body of given dimensions is seen. Now, on measuring the angular dimension of the sun, with accurate instruments, at different seasons of the year, it has been found that his dimensions increase and diminish, and that these variations correspond exactly with the supposition, that the earth moves in an elliptical orbit. If, for instance, his apparent diameter be taken in March, and then again in July, it will be found to have diminished, which diminution is only to be accounted for, by supposing that he is at a greater distance from the observer in July than in March. From July, his angular diameter gradually increases, till January, when it again diminishes, and continues to diminish, until July. By many observations, it is found, that the greatest apparent diameter of the sun, and therefore his least distance from us, is in January, and his least diameter, and therefore his greatest

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123. At what season of the year is the sun at the greatest, and at what season the least distance from the earth? How is it ascertained that the earth moves in an elliptical orbit, by the appearance of the sun? When does the sun appear under the greatest apparent diameter, and *when under the least?* How much farther is the sun from us in July *than in January?* What effect does this difference produce on the earth?

distance, is in July. The actual difference is about three millions of miles, the sun being that distance further from the earth in July than in January. This, however, is only about one sixtieth of his mean distance from us, and the difference we should experience in his heat, in consequence of this difference of distance, will therefore be very small. Perhaps the effect of his proximity to the earth may diminish, in some small degree, the severity of winter.

124. "The heat of summer, and the cold of winter, must therefore arise from the difference in the meridian altitude of the sun, and in the time of his continuance above the horizon. In summer, the solar rays fall on the earth in nearly a *perpendicular* direction, and his powerful heat is then constantly accumulated by the long days and short nights of the season. In winter, on the contrary, the solar rays fall so *obliquely* on the earth, as to produce little warmth, and the small effect they do produce during the short days of that season, is almost entirely destroyed by the long nights which succeed. The difference between the effects of perpendicular and oblique rays, seems to depend, in a great measure, on the different extent of surface over which they are spread. When the rays of the sun are made to pass through a convex lens, the heat is increased, because the number of rays which naturally covered a large surface, are then made to cover a smaller one, so that the power of the glass depends on the number of rays thus brought to a focus. If, on the contrary, the rays of the sun are suffered to pass through a concave lens, their natural heating power is diminished, because they are dispersed, or spread over a wider surface than before.

125. "Now, to apply these different effects to the summer and winter rays of the sun, let us suppose that the rays falling perpendicularly on a given extent of surface, impart to it a certain degree of heat; then it is obvious, that if the same number of rays be spread over twice that extent of surface, their heating power would be diminished in proportion, and that only half the heat would be imparted. This is the effect produced by the sun's rays in the winter. They fall so

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124. How are the heat of summer and the cold of winter accounted for? Why do the perpendicular rays of summer produce greater effects *than the oblique rays* of winter? How is this illustrated by the convex *and concave lenses*?—125. How is the actual difference of the summer *and winter rays shown?*

obliquely on the earth, as to occupy nearly double the space that the same number of rays do in the summer. This is illustrated by Fig. 21, where the number of rays, both in winter and summer, are supposed to be the same. But, it will be observed, that the winter rays, owing to their oblique direction, are spread over nearly twice as much surface as those of summer.

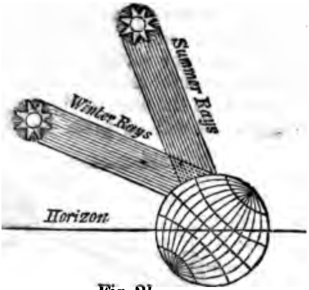

Fig. 21.

126. It may, however, be remarked, that the hottest season is not usually at the exact time of the year when the sun is most vertical, and the days the longest, as is the case towards the end of June, but some time afterwards, as in July and August. To account for this, it must be remembered, that when the sun is nearly vertical, the earth accumulates more heat by day than it gives out at night, and that this accumulation continues to increase after the days begin to shorten, and, consequently, the greatest elevation of temperature is some time after the longest days. For the same reason, the thermometer generally indicates the greatest degree of heat at two or three o'clock on each day, and not at twelve o'clock, when the sun's rays are most powerful.

FIGURE OF THE EARTH.

127. Astronomers have proved that all the planets, together with their satellites, have the shape of the sphere, or globe, and hence, by analogy, there was every reason to suppose, that the earth would be found of the same shape; and several phenomena tend to prove, beyond all doubt, that this is its form. The figure of the earth is not, however, exactly that of a globe, or ball, because its diameter is about 34 miles less from pole to pole, than it is at the equator. But that its general figure is that of a sphere, or ball, is proved by many circumstances.

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126. Why is not the hottest season of the year at the period when the days are longest and the sun most vertical?—127. What is the general figure of the earth? How much less is the diameter of the earth at the poles than at the equator?

128. "When a person is at sea, or standing on the seashore, the first part of a ship seen at a distance, is its mast. As the vessel advances, the mast rises higher and higher above the horizon, and finally the hull, and whole ship, become visible. Now, were the earth's surface an exact plane, no such appearance would take place, for we should then see the hull long before the mast or rigging, because it is much the largest object. It will be plain by Fig. 22, that were the ship, A, elevated so that the hull should be on a horizontal line with the eye, the whole ship would be visible, instead of the topmast, there being no reason, except the convexity of the earth, why the whole ship should not be visible at A, as well as at B. We know, for the same reason, that in passing over a hill, the tops of the trees are seen, before we can discover the ground on which they stand; and that when a man approaches from the opposite side of a hill, his head is seen before his feet."

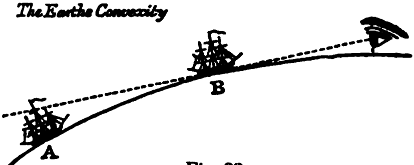

Fig. 22.

129. "If we sail out of sight of land, whether we stand on the deck of the ship, or climb the mast, we see the surface of the sea—not losing itself in distance and mist, but terminated by a sharp, clear, well-defined line, or *offing*, as it is called, which runs all round us in a circle, having our station for its centre. That this line is really a circle, we conclude, first, from the perfect apparent similarity of all its parts; and, secondly, from the fact of all its parts appearing at the same distance from us, and that, evidently, a moderate one; and, thirdly, from this, that its apparent *diameter*, measured with an instrument called the *dip sector*, is the same (except under some singular atmospheric circumstances, which produce a temporary distortion of its outline,) in whatever direction the

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128. How is the convexity of the earth proved by the approach of a ship at sea? Explain Fig. 22. What other proofs of the globular shape *of the earth are mentioned?*—129. What proof is derived from the offing *observed at sea?*

measure is taken—properties which belong only to the circle among geometrical figures. If we ascend a high eminence on a plain (for instance, one of the Egyptian pyramids), the same holds good.

130. "Masts of ships, however, and the edifices erected by man, are trifling eminences compared to what nature itself affords: Etna, Teneriffe, Mowna Roa, are eminences from which no contemptible *aliquot* part of the whole earth's surface can be seen; but from these again—in those few and rare occasions when the transparency of the air will permit the real boundary of the horizon, the true sea-line, to be seen—the very same appearances are witnessed, but with this remarkable addition, viz., that the angular *diameter* of the visible area, as measured by the dip sector, is materially *less* than at a lower level; or, in other words, that the *apparent size* of the earth has sensibly diminished as we have receded from its surface, while yet the *absolute quantity* of it seen at once has been increased. The same appearances are observed universally, in every part of the earth's surface visited by man. Now, the figure of a body, which, however seen, always appears *circular*, can be no other than a sphere or globe."—*Herschel's Astronomy.*

131. "It is a well known fact also, that navigators have set out from a particular port, and by sailing continually westward, have passed around the earth, and again reached the port from which they sailed. This could never happen, were the earth an extended plane, since then the longer the navigator sailed in one direction, the further he would be from home.

132. "Another proof of the spheroidal form of the earth, is the figure of its shadow on the moon, during eclipses, which shadow is always bounded by a circular line.

133. "These circumstances prove, beyond all doubt, that the form of the earth is globular, but that it is not an exact sphere; and that it is depressed or flattened at the poles, is shown by the difference in the lengths of pendulums vibrating seconds at the poles, and at the equator.

134. It is necessary to state that the vibrations of the pendulum depend on the attraction of gravitation, and that

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130. What additional appearance is presented from lofty eminences on the earth's surface?—131—133. What further proofs are there of the globular form of the earth?—134. How is it shown by the vibrations of the pendulum that the earth is flattened at the poles?

as the centre of the earth is the centre of this attraction, so the nearer this instrument is carried to that point, the stronger will be the attraction, and consequently the more frequent its vibrations. From a great number of experiments, it has been found that a pendulum, which vibrates seconds at the equator, has its number of vibrations increased when it is carried towards the poles; and as its number of vibrations depends upon its length, a clock which keeps accurate time at the equator, must have its pendulum lengthened at the poles. And so, on the contrary, a clock going correctly at, or near the poles, must have its pendulum shortened, to keep exact time at the equator. Hence the force of gravity is greatest at the poles, and least at the equator.

135. "The manner in which the figure of the earth differs from that of a sphere, is represented by Fig. 23, where N is the north pole, and S the south pole, the line from one of these points to the other being the axis of the earth, and the line crossing this, the equator. It will be seen by this figure, that the surface of the earth, at the poles, is nearer its centre than the surface at the equator. The actual difference between the polar and equatorial diameters is in the proportion of 300 to 301. The earth is therefore called an *oblate spheroid*, the word oblate signifying the reverse of oblong, or shorter in one direction than in another.

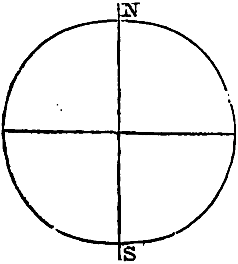

Fig. 23.

136. "The compression of the earth at the poles, and the consequent accumulation of matter at the equator, is probably the effect of its diurnal revolution, while it was in a soft or plastic state. If a ball of soft clay, or putty, be made to revolve rapidly, by means of a stick passed through its centre, as an axis, it will swell out in the middle, or equator, and be depressed at the poles, assuming the precise figure of the earth. This figure is the natural and obvious conse-

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135. In what proportion is the polar less than the equatorial diameter? What is the earth called in reference to this figure?—136. How is it *supposed that it* came to have this form? How is the form of the earth *illustrated by experiment?* Explain the reason why a plastic ball will *swell at the equator*, when made to revolve.

quence of the *centrifugal force*, which operates to throw the matter off in proportion to its distance from the axis of motion, and the rapidity with which the ball is made to revolve. The parts about the equator would therefore tend to fly off, and leave the other parts, in consequence of the centrifugal force, while those about the poles, being nearer the centre of motion, would receive a much smaller impulse. Consequently the ball would swell, or bulge out at the equator, which would produce a corresponding depression at the poles.

137. "The weight of a body at the poles is found to be greater than at the equator, not only because the poles are nearer the centre of the earth than the equator, but because the centrifugal force there tends to lessen its gravity. The wheels of machines which revolve with the greatest rapidity are made in the strongest manner, otherwise they will fly in pieces, the centrifugal force not only overcoming the gravity, but the cohesion of their parts.

138. "It has been found by calculation, that if the earth turned over once in 84 minutes and 43 seconds, the centrifugal force at the equator would be equal to the power of gravity there, and that bodies would entirely lose their weight. If the earth revolved more rapidly than this, all the buildings, rocks, mountains, and men, at the equator, would not only lose their weight, but would fly from the earth, as mud does from a carriage-wheel in rapid motion.

SOLAR AND SIDEREAL TIME.

139. "The stars appear to go round the earth in 23 hours, 56 minutes, and 4 seconds, while the sun appears to perform the same revolution in 24 hours, so that the stars gain 3 minutes and 56 seconds upon the sun every day. In a year, this amounts to a day, or to the time taken by the earth to perform one diurnal revolution. It therefore happens, that when time is measured by the stars, there are 366 days in the year, or 366 diurnal revolutions of the earth; while, if measured by the sun from one meridian to another, there

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137. What two causes render the weights of bodies less at the equator than at the poles?—138. What would be the consequence on the weights of bodies at the equator, did the earth turn over once in 84 minutes and 43 seconds?—139. The stars appear to move round the earth in less time than the sun; what does the difference amount to in a *year? What is the year, measured by a star, called? What is that measured by the sun called?*

are only 365 whole days in the year. The former are called the *sidereal*, and the latter *solar* days.

140. "To account for this difference, we must remember that the earth, while she performs her daily revolutions, is constantly advancing in her orbit, and that, therefore, at 12 o'clock to-day she is not precisely at the same place in respect to the sun that she was at 12 o'clock yesterday, or will be to-morrow. But the fixed stars are at such an amazing distance from us, that the earth's orbit, in respect to them, is but a point; and, therefore, as the earth's diurnal motion is perfectly uniform, she revolves from any given star to the same star again, in exactly the same period of absolute time. The orbit of the earth, were it a solid mass, instead of an imaginary circle, would have no appreciable length or breadth, when seen from a fixed star, and therefore, whether the earth performed her diurnal revolutions at a particular station, or while passing round in her orbit, would make no appreciable difference with respect to the star. Hence the same star, at every complete daily revolution of the earth, appears precisely in the same direction at all seasons of the year. The moon, for instance, would appear at exactly the same point, to a person who walks round a circle of a hundred yards in diameter, and for the same reason a star appears in the same direction from all parts of the earth's orbit, though 190 millions of miles in diameter.

141. "If the earth had only a diurnal motion, her revolution, in respect to the sun, would coincide exactly with the same revolution in respect to the stars; but while she is making one revolution on her axis towards the east, she advances in the same direction about one degree in her orbit, so that to bring the same meridian towards the sun, she must make a little more than one entire revolution. To make this plain, suppose the sun, S, Fig. 24, to be exactly on a meridian line marked at E, on the earth A, on a given day. On the next day, the earth, instead of being at A, as on the day before, advances in its orbit to B, and in the meantime having completed her revolution, in respect to a star, the same

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140. How is the difference in time between the solar and sidereal year accounted for? The earth's orbit is but a point, in reference to a star; how is this illustrated?—**141.** Had the earth only a diurnal revolution, *would the sidereal* and solar time agree? Show by Fig. 24 how *sidereal differs from* solar time. Why does not the earth turn the same *meridian to the* sun at the same time every day?

meridian line is not brought under the sun, as on the day before, but falls short of it, as at E, so that the earth has to

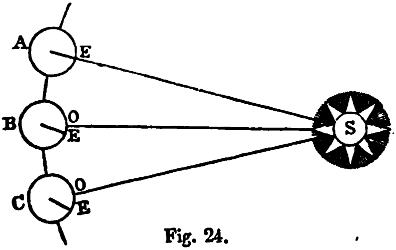

Fig. 24.

perform more than a revolution, by the distance from E to O, in order to bring the same meridian again under the sun. So on the next day, when the earth is at C, she must again complete more than two revolutions, since leaving A, by the space from E to O, before it will again be noon at E.

142. "Thus it is obvious, that the earth must complete one revolution, and a portion of a second revolution, equal to the space she has advanced in her orbit, in order to bring the same meridian back again to the sun. This small portion of a second revolution amounts daily to the 365th part of her circumference, and therefore, at the end of the year, to one entire rotation, and hence, in 365 days, the earth actually turns on her axis 366 times. Thus, as one complete rotation forms a sidereal day, there must, in the year, be one sidereal more than there are solar days, one rotation of the earth, with respect to the sun, being lost, by the earth's yearly revolution. The same loss of a day happens to a traveller, who, in passing round the earth towards the west, reckons his time by the rising and setting of the sun. If he pass round towards the east, he will gain a day for the same reason.

EQUATION OF TIME.

143. "As the motion of the earth about its axis is perfectly

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142. How many times does the earth turn on her axis in a year? Why does she turn more times than there are days in the year?—143. Why are the solar days sometimes greater, and sometimes less, than 24 hours? What is the difference between the time of a sun dial and a clock called? What are the causes of the difference between the sun and clock?

uniform, the sidereal days, as we have already seen, are exactly of the same length, in all parts of the year. But as the orbit of the earth, or the apparent path of the sun, is inclined to the earth's axis, and as the earth moves with different velocities in different parts of its orbit, the solar, or natural days, are sometimes greater and sometimes less than 24 hours, as shown by an accurate clock. The consequence is, that a true sun dial, or noon mark, and a true time piece, agree with each other only a few times in a year. The difference between the sun dial and clock, thus shown, is called the *equation of time.* The difference between the sun and a well regulated clock, thus arises from two causes, the inclination of the earth's axis to the ecliptic, and the elliptical form of the earth's orbit.

144. "That the earth moves in an ellipse, and that its motion is more rapid sometimes than at others, as well as that the earth's axis is inclined to the ecliptic, have already been explained and illustrated. It remains, therefore, to show how these two combined causes, the elliptical form of the orbit, and the inclination of the axis, produce the disagreement between the sun and clock. In this explanation, we must consider the sun as moving around the ecliptic, while the earth revolves on her axis.

145. "*Equal*, or *mean* time is that which is reckoned by a clock, supposed to indicate exactly 24 hours, from 12 o'clock on one day, to 12 o'clock on the next day. *Apparent* time is that which is measured by the apparent motion of the sun in the heavens, as indicated by a meridian line, or sun dial.

146. "Were the earth's orbit a perfect circle, and her axis perpendicular to the plane of this orbit, the days would be of a uniform length, and there would be no difference between the clock and the sun: both would indicate 12 o'clock at the same time, on every day in the year. But on account of the inclination of the earth's axis to the ecliptic, unequal portions of the sun's apparent path through the heavens will pass any meridian in equal times. This may be readily explained to the pupil, by means of an artificial globe; but perhaps it will be understood by the following diagram:—

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144. In explaining equation of time, what motion is considered as *belonging* to the sun, and what motion to the earth?—145. What is *equal or mean time?* What is apparent time?—146. Under what *suppositions would* the days be of equal length?

147. "Let A N B S, Fig. 25, be the concave of the heavens, in the centre of which is the earth. Let the line A B, be the equator, extending through the earth and the heavens,

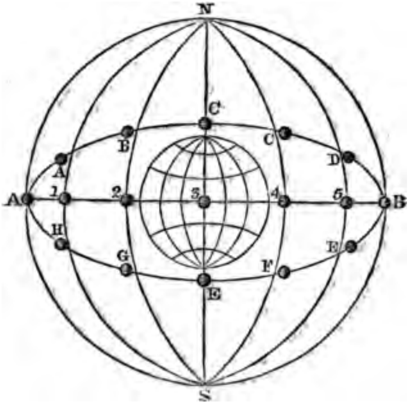

Fig. 25.

and let A, A, B, C, C, and D, be the ecliptic, or the apparent path of the sun through the heavens. Also, let A, 1, 2, 3, 4, 5, be equal distances on the equator, and A, A, B, C, C, and D, equal portions of the ecliptic, corresponding with A 1, 2, 3, 4, and 5. Now we will suppose that there are two suns, namely, a false, and a real one; that the false one passes through the celestial equator, which is only an extension of the earth's equator, to the heavens; while the real sun has an apparent revolution through the ecliptic; and that they both start from the point A, at the same instant. The false sun is supposed to pass through the celestial equator in the same time that the real one passes through the ecliptic, but not through the same meridians at the same time, so that the false sun arrives at the points 1, 2, 3, 4, and 5, at the time when the real sun arrives at the points A, B, C, and C.

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147. In Fig. 25, which is the celestial equator, and which the ecliptic? Through which of these circles does the false, and through which does the true sun pass? When the real sun arrives at A, and the false one at 1, are they both on the same meridian? Which is then the more *westward?*

148. "When the two suns were at A, the starting point, they were both on the same meridian, but when the fictitious sun comes to 1, and the real sun to A, they are not in the same meridian, but the real sun is westward of the fictitious one, the real sun being at A while the false sun is on the meridian 1; consequently, as the earth turns on its axis from west to east, any particular place will come under the sun's real meridian, sooner than under the fictitious sun's meridian; that is, it will be 12 o'clock by the true sun, before it is 12 o'clock by the false sun, or by a true clock; but were the true sun in place of the false one, the sun and clock would agree. While the true sun is passing through that quarter of his orbit, from A to C, and the fictitious sun from 1 to 3, it will always be noon by the true sun before it is noon by the false sun, and during this period the sun will be *faster* than the clock.

149. "When the true sun arrives at C, and the false one at 3, they are both on the same meridian, and the sun and clock agree. But while the real sun is passing from C to B, and the false one from 3 to B, any meridian comes later under the true sun than it does under the false, and then it is noon by the sun after it is noon by the clock, and the sun is then said to be *slower* than the clock. At B, both suns are again on the same meridian, and then again the sun and clock agree.

150. "We have thus followed the real sun through one half of his *true apparent* place in the heavens, and the false one through half the celestial equator, and have seen that the two suns, since leaving the point A, have been only twice on the same meridian at the same time. It has been supposed that the two suns passed through equal arcs in equal times, the real sun through the ecliptic, and the false one through the equator. The place of the false sun may be considered as representing the place where the real sun would be, in case the earth's axis had no inclination, and consequently it

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148. When the two suns are at 1 and A, why will any meridian come first under the real sun? Were the true sun in place of the false one, why would the sun and clock agree? While the suns are passing from A to C, and from 1 to 3, will the sun be faster or slower than the clock?—149. When the two suns are at C and 3, why will the sun *and clock agree?* While the real sun is passing from B to C, which is *faster, the clock or* sun?—150. What does the place of the false sun *represent in Fig. 25?*

agrees with the clock every 24 hours. But the true sun, as he passes round in the ecliptic, comes to the same meridian, sometimes sooner, and sometimes later, and in passing around the other half of the ecliptic, or in the other half year, the same variations succeed each other.

151. "The two suns are supposed to depart from the point A, on the 20th of March, at which time the sun and clock coincide. From this time, the sun is *faster* than the clock, until the two suns come together at the point C, which is on the 21st of June, when the sun and clock again agree. From this period the sun is *slower* than the clock, until the 23d of September, and *faster* again until the 21st of December, at which time they agree as before.

152. "We have thus seen how the inclination of the earth's axis, and the consequent obliquity of the equator to the ecliptic, cause the sun and clock to disagree, and on what days they would coincide, provided no other cause interfered with their agreement. But although the inclination of the earth's axis would bring the sun and clock together on the above-mentioned days, yet this agreement is counteracted by another cause, which is the elliptical form of the earth's orbit, and though the sun and clock do agree four times in the year, it is not on any of the days above mentioned.

153. "It has been shown by Fig. 15, that the earth moves more rapidly in one part of its orbit than in another. When it is nearest the sun, which is in the winter, its velocity is greater than when it is most remote from him, as in the summer. Were the earth's orbit a perfect circle, the sun and clock would coincide on the days above specified, because then the only disagreement would arise from the inclination of the earth's axis. But since the earth's distance from the sun is constantly changing, her rate of velocity also changes, and she passes through unequal portions of her orbit in equal times. Hence, on some days, she passes through a greater portion of it than on others, and thus this becomes another cause of the inequality of the sun's apparent motion.

151, 152. The inclination of the earth's axis would make the sun and clock agree in March, and the other months above named; why then do they not actually agree at those times?—153. Were the earth's orbit a perfect circle, on what days would the sun and clock agree?—How does the form of the earth's orbit interfere with the agreement of the sun and clock on those days?

154. "The elliptical form of the earth's orbit would prevent the coincidence of the sun and clock at all times, except when the earth is at the greatest distance from the sun, which happens on the 1st of July, and when she is at the least distance from him, which happens on the 1st of January. As the earth moves faster in the winter than in the summer, from this cause, the sun would be faster than the clock from the 1st of July to the 1st of January, and then slower than the clock from the 1st of January to the 1st of July.

155. "We have now explained, separately, the two causes which prevent the coincidence of the sun and clock. By the first cause, which is the inclination of the earth's axis, they would agree four times in the year; and by the second cause, the irregularity of the earth's motion, they would coincide only twice in the year. Now, these two causes counteract the effects of each other, so that the sun and clock do not coincide on any of the days, when either cause, taken singly, would make an agreement between them. The sun and clock, therefore, are together, only when the two causes balance each other; that is, when one cause so counteracts the other, as to make a mutual agreement between them. This effect is produced four times in the year; namely, on the 15th of April, 15th of June, 31st of August, and 24th of December. On these days, the sun, and a clock keeping exact time, coincide, and on no others. The greatest difference between the sun and clock, or between the apparent and mean time, is 16½ minutes, which takes place about the 1st of November.

PRECESSION OF THE EQUINOXES.

156. "A *tropical* year is the time it takes the sun to pass from one equinox, or tropic, to the same tropic, or equinox, again. A *sidereal* year is the time it takes the sun to perform his apparent annual revolution, from a fixed star, to the same fixed star again.

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154. At what times would the form of the earth's orbit bring the sun and clock to agree?—155. The inclination of the earth's axis would make the sun and clock agree four times in the year, and the form of the earth's orbit would make them agree twice in the year; now show the reason why they do not agree from these causes on the above-mentioned days, and why they do agree on other days? On what days do *the sun and clock* agree?—156. What is a tropical year? What is a *sidereal year?*

157. "Now it has been found that these two complete revolutions are not finished in exactly the same time, but that it takes the sun about 20 minutes longer to complete his apparent revolution in respect to the *star*, than it does in respect to the *equinox*, and hence the *sidereal year* is about 20 minutes longer than the *tropical year*. The revolution of the earth from equinox to equinox, again, therefore, *precedes* its complete revolution in the ecliptic by about 20 minutes, for the absolute revolution of the earth is measured by its return to the fixed star, and not by the return of the sun to the same equinoctial point. This apparent falling back of the equinoctial point, so as to make the time when it meets the sun *precede* the time when the earth makes its complete revolution in respect to the star, is called the *precession of the equinoxes*.

158. "The distance which the sun thus gains upon the fixed star, or the difference between the sun and star, when the sun has arrived at the equinoctial point, amounts to 50 seconds of a degree, thus making the equinoctial point recede 50 seconds of a degree, (when measured by the signs of the zodiac,) westward, every year, contrary to the sun's annual progressive motion in the ecliptic.

159. "To illustrate this by a figure, suppose S, Fig. 26,

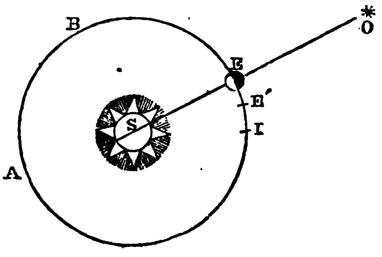

Fig. 26.

to be the sun, E the earth, and O a fixed star, all in a

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157. What is the difference in the time which it takes the sun to complete his revolution in respect to a star, and in respect to the equinox? Explain what is meant by the precession of the equinoxes.—158. How many seconds of a degree does the equinox recede every year, when the sun's place is compared with a star?—159. How does Fig. 26 illustrate the *precession* of the equinoxes?

straight line with respect to each other. Let it be supposed that this opposition takes place on the 21st of March, at the vernal equinox, and that at that time the earth is exactly between the sun and the star. Now when the earth has performed a complete revolution around its orbit B, A, as measured by the star, she will arrive at precisely the same point where she now is. But it is found that when the earth comes to the same equinoctial point, the next year, she has not gone her complete revolution in respect to the star; the equinoctial point having fallen back with respect to the star, during the year, from E to E′, so that the earth, after having completed her revolution, in respect to the equinox, has yet to pass the space from E′ to E, to complete her revolution in respect to the star.

160. "The space from E to E′, being 50 seconds of a degree, and the equinoctial point falling this space every year short of the place where the sun and this point agreed the year before, it is obvious, that on the next revolution of the earth, the equinox will not be found at E, but at I, so that the earth, having completed her second revolution in respect to the sun when at I, will still have to pass from I to E, before she completes another revolution in respect to the star.

161. "The precession of the equinoxes, being 50 seconds of a degree, every year, contrary to the sun's apparent motion, or about 20 minutes, in time, short of the point where the sun and equinoxes coincided the year before, it follows, that the fixed stars, or those in the sign of the zodiac, move forward every year 50 seconds, with respect to the equinoxes.

162. "In consequence of this precession, in 2160 years, those stars which now appear in the beginning of the sign Aries, for instance, will then appear in the beginning of Taurus, having moved forward one whole sign, or 30 degrees, with respect to the equinoxes, or the equinoxes having gone backwards 30 degrees, with respect to the stars. In 12,960

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160. Explain Fig. 26, and show from what points the equinoxes fall back from year to year.—161. How many minutes in time is the precession of the equinoxes per year?—162. What effect does this precession produce on the fixed stars? How many years is a star in going forward one degree, in respect to the equinoxes? In how many years *will the stars* appear to have passed half around the heavens? In *what period* will the earth appear to have gone backwards one whole *revolution?*

years, or 6 times 2160 years, therefore, the stars will appear to have moved forward one-half of the whole circle of the heavens, so that those which now appear in the first degree of the sign Aries, will then be in the opposite point of the zodiac, and, therefore, in the first degree of Libra. And in 12,600 years more, because the equinoxes will have fallen back the other half of the circle, the stars will appear to have gone forward from Libra to Aries, thus completing the whole circle of the zodiac. Thus, in about 26,000 years, the equinox will have gone backwards a whole revolution around the axis of the ecliptic, and the stars will appear to have gone forward the whole circle of the zodiac.

163. "The discovery of the precession of the equinoxes has thrown much light on ancient astronomy and chronology, by showing an agreement between ancient and modern observations, concerning the places of the signs of the zodiac, not to be reconciled in any other manner. A complete explanation of the cause which occasions the precession of the equinoxes, would require the aid of the most abstruse mathematics, and therefore cannot be properly introduced here. The cause itself may, however, be stated in a few words. It has already been explained that the revolution of the earth round its axis has caused an excess of matter to be accumulated at the equator, and hence, that the equatorial is greater than the polar diameter by 26 miles. Now the attraction of the sun and moon on this accumulated matter at the equator has the effect of slowly turning the earth about the axis of the ecliptic, and thus causing the precession of the equinoxes.

THE MOON.

164. The moon is of about the fiftieth part of the bulk of the earth; the mean or average distance of its centre from that of the earth is about 237,000 miles. "This distance," observes Sir J. Herschel, "great as it is, is little more than one-fourth of the diameter of the sun's body, so that the whole globe of the sun would nearly twice include the whole

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163. In what respect is the precession of the equinoxes an important subject? What is the cause of the precession of the equinoxes?—164. What is the size of the moon as compared with that of the earth? What is its mean distance from the earth? What is the distance of the moon from the earth, as compared with the diameter of the sun's body?

orbit of the moon; a consideration wonderfully calculated to raise our ideas of that stupendous luminary!"

165. "While the earth revolves round the sun, the moon revolves round the earth, completing her revolution once in 27 days, 7 hours, and 43 minutes, and at the distance of 240,000 miles from the earth. The period of the moon's change, that is, from new moon to new moon again, is 29 days, 12 hours, and 44 minutes.

166. "The time of the moon's revolution round the earth is called her *periodical* month; and the time from change to change is called her *synodical* month. If the earth had no annual motion, these two periods would be equal, but because the earth goes forward in her orbit, while the moon goes round the earth, the moon must go as much farther, from change to change, to make these periods equal, as the earth goes forward during that time, which is more than the twelfth part of her orbit, there being more than twelve lunar periods in the year.

167. "These two revolutions may be familiarly illustrated by the motions of the hour and minute hands of a watch. Let us suppose the 12 hours marked on the dial plate of a watch to represent the 12 signs of the zodiac through which the sun seems to pass in his yearly revolution, while the hour hand of the watch represents the sun, and the minute hand the moon. Then, as the hour hand goes round the dial plate once in 12 hours, so the sun apparently goes round the zodiac once in 12 months; and as the minute hand makes 12 revolutions to one of the hour hand, so the moon makes 12 revolutions to one of the sun. But the moon, or minute hand, must go more than once round, from any point on the circle, where it last came in conjunction with the sun, or hour hand, to overtake it again, since the hour hand will have moved forward of the place where it was last overtaken, and consequently the next conjunction must be forward of the place where the last happened. During an hour, the hour hand describes the twelfth part of the circle, but the minute hand has not only to go round

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165. How long is the moon in completing her revolution round the earth? What is the period from new moon to new moon again?—166. What are these two periods called? Why are not the periodical and synodical months equal?—167. How are these two revolutions of the moon illustrated by the two hands of a watch? Mention the time of several conjunctions between the two hands of a watch?

the whole circle in an hour, but also such a portion of it, as the hour hand has moved forward since they last met. Thus, at 12 o'clock, the hands are in conjunction; the next conjunction is 5 minutes 27 seconds past I o'clock; the next, 10 min. 54 sec. past II o'clock; the 3d, 16 min. 21 sec. past III; the 4th, 21 min. 49 sec. past IV; the 5th, 27 min. 10 sec. past V; the 6th, 32 min. 43 sec. past VI; the 7th, 38 min. 10 sec. past VII; the 8th, 43 min. 38 sec. past VIII; the 9th, 49 min. 5 sec. past IX; the 10th, 54 min. 32 sec. past X; and the next conjunction is at XII.

168. "Now although the moon passes around the earth in 27 days 7 hours and 43 minutes, yet her change does not take place at the end of this period, because her changes are not occasioned by her revolutions alone, but by her coming periodically into the same position in respect to the sun. At her change, she is in conjunction with the sun, when she is not seen at all, and at this time astronomers call it *new moon*, though generally, we say it is new moon two days afterwards, when a small part of her face is to be seen. The reason why there is not a new moon at the end of 27 days, will be obvious, from the motions of the hands of a watch; for we see that more than a revolution of the minute hand is required to bring it again in the same position with the hour hand, by about the twelfth part of the circle.

169. "The same principle is true in respect to the moon; for as the earth advances in its orbit, it takes the moon 2 days 5 hours and 1 minute longer to come again in conjunction with the sun, than it does to make her monthly revolution round the earth; and this 2 days 5 hours and 1 minute being added to 27 days 7 hours and 43 minutes, the time of the periodical revolution, makes 29 days 12 hours and 44 minutes, the period of her synodical revolution.

170. "The moon always presents the same side, or face, towards the earth, and hence it is evident that she turns on her axis but once, while she is performing one revolution round the earth, so that the inhabitants of the moon have

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168. Why do not the moon's changes take place at the periods of her revolution around the earth?—169. How much longer does it take the moon to come again in conjunction with the sun, than it does to perform her periodical revolution?—170. How is it proved that the moon makes but one revolution on her axis as she passes around the earth? One half of the moon is never in the dark; explain why this is so. How long are the days and the nights in the other half?

but one day, and one night, in the course of a lunar month. One half of the moon is never in the dark, because when this half is not enlightened by the sun, a strong light is reflected to her from the earth, during the sun's absence. The other half of the moon enjoys alternately two weeks of the sun's light, and two weeks of total darkness.

171. "The moon is a globe, like our earth, and, like the earth, shines only by the light reflected from the sun; therefore, while that half of her which is turned towards the sun is enlightened, the other half is in darkness. Did the moon shine by her own light, she would be constantly visible to us, for then, being an orb, and every part illuminated, we should see her constantly full and round, as we do the sun.

172. "One of the most interesting circumstances to us, respecting the moon, is the constant changes which she undergoes, in her passage around the earth. When she first appears, a day or two after her change, we can see only a small portion of her enlightened side, which is in the form of a crescent; and at this time she is commonly called *new moon*. From this period, she goes on increasing, or showing more and more of her face every evening, until at last she becomes round, and her face fully illuminated. She then begins again to decrease, by apparently losing a small section of her face, and the next evening another small section from the same part, and so on, decreasing a little every day, until she entirely disappears; and having been absent a day or two, re-appears, in the form of a crescent, or new moon, as before. When the moon disappears, she is said to be in *conjunction*, that is, she is in the same direction from us with the sun. When she is full, she is said to be in *opposition*, that is, she is in that part of the heavens opposite to the sun, as seen by us.

173. "The different appearances of the moon from *new* to *full*, and from *full* to *change*, are owing to her presenting different portions of her enlightened surface towards us at different times. These appearances are called the *phases* of the moon, and are easily accounted for, and understood, by

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171. How is it shown that the moon shines only by reflected light?—172. When is the moon said to be in conjunction with the sun, and when in opposition to the sun?—173. What are the phases of the moon? Describe *Fig. 27*, and show how the moon passes from change to full, and *from full to change?*

the following figure. Let S, Fig. 27, be the sun, E the earth, and A, B, C, D, E, the moon in different parts of her orbit. 1. Now when the moon changes, or is in conjunction with the sun, as at A, her dark side is turned towards the earth, and she is invisible, as represented at A′. The sun always shines on one half of the moon, in every direction, as represented at A and B, on the inner circle; but we at the earth can see only such portions of the enlightened half as are turned towards us. 2. After her change, when she has moved from A to B, a small part of her illuminated side comes in sight, and she appears horned, as at B′, and is then called the *new* moon. 3. When she arrives at C, several days afterwards, one half of her disk is visible, and she appears as at C′, her appearance being the same in both circles. At this point she is said to be in her *first quarter*, because she has passed through a quarter of her orbit, and is 90 degrees from the place of her conjunction with the sun. 4. At D, she shows us still more of her enlightened side, and is then said to appear *gibbous*, as at D′. 5. When she comes to E, her whole enlightened side is turned towards the earth, and she appears in all the splendour of a *full* moon. During the other half of her revolution, she daily shows less and less of her illuminated side, until she again becomes invisible by her conjunction with the sun. Thus, in passing from her conjunction A′, to her full E′, the moon appears every day to increase, while in going from her full to her conjunction again, she appears to us constantly to decrease, but as seen from the sun, she appears always full.

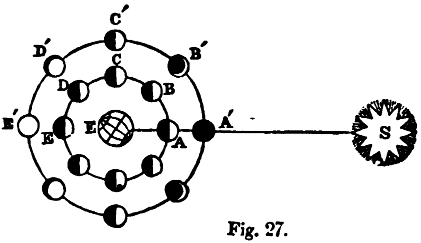

Fig. 27.

174. "*How the earth appears at the moon.*—The earth, seen by the inhabitants of the moon, exhibits the same phases

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174. What is said concerning the phases of the earth, as seen from the moon? When is the earth in her change to the people of the moon?

that the moon does to us, but in a contrary order. When the moon is in her conjunction, and consequently invisible to us, the earth appears full to the people of the moon, and when the moon is full to us, the earth is dark to them.

175. "The earth appears thirteen times larger to the inhabitants of the moon than the moon does to us. As the moon always keeps the same side towards the earth, and turns on her axis only as she moves round the earth, we never see her opposite side. Consequently, the inhabitants of the moon who live on the opposite side to us never see the earth at all. To those who live on the middle of the side next to us, our earth is always visible, and directly over head, turning on its axis nearly thirty times as rapidly as the moon, for she turns only once in about thirty days. A lunar astronomer, who should happen to live directly opposite to that side of the moon, which is next to us, would have to travel a quarter of the circumference of the moon, or about 1500 miles, to see our earth above the horizon, and if he had the curiosity to see such a glorious orb, in its full splendour over his head, he must travel 3000 miles. But if his curiosity equalled that of the terrestrials, he would be amply compensated by beholding so glorious a nocturnal luminary, a moon thirteen times as large as ours.

176. "That the earth shines upon the moon as the moon does upon us, is proved by the fact that the outline of her whole disk may be seen, when only a part of it is enlightened by the sun. Thus when the sky is clear, and the moon only two or three days old, it is not uncommon to see the brilliant new moon, with her horns enlightened by the sun, and at the same time, the old moon faintly illuminated by reflection from the earth. This phenomenon is sometimes called 'the old moon in the new moon's arms.'

177. "It was a disputed point among former astronomers, whether the moon has an atmosphere; but the more recent discoveries have decided that she has an atmosphere, though there is reason to believe that it is much less dense than ours.

178. "*Surface of the moon.*—When the moon's surface is examined through a telescope, it is found to be wonderfully diversified, for besides the dark spots perceptible to the naked

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175. Why do those who live on one side of the moon never see the *earth?—176. How* is it known that the earth shines upon the moon, as *the moon does upon* us?—177. What is said concerning the moon's at*mosphere?—178.* How high are some of the mountains, and how deep *the caverns of the moon?*

eye, there are seen extensive valleys, and long ridges of highly elevated mountains. Some of these mountains, according to Dr Herschel, are four miles high, while hollows more than three miles deep, and almost exactly circular, appear excavated on the plains. Astronomers have been at vast labour to enumerate, figure, and describe, the mountains and spots on the surface of the moon, so that the latitude and longitude of about 100 spots have been ascertained, and their names, shapes, and relative positions given. A still greater number of mountains have been named, and their heights and the length of their bases detailed.

179. "The deep caverns, and broken appearance of the moon's surface, long since induced astronomers, to believe that such effects were produced by volcanoes, and more recent discoveries have seemed to prove that this suggestion was not without foundation. Dr Herschel saw, with his telescope, what appeared to him three volcanoes in the moon, two of which were nearly extinct, but the third was in the actual state of eruption, throwing out fire, or other luminous matter, in vast quantities. It was formerly believed that several large spots, which appeared to have plain surfaces, were seas, or lakes, and that a part of the moon's surface was covered with water, like that of our earth. But it has been found, on closely observing these spots, when they were in such a position as to reflect the sun's light to the earth, had they been water, that no such reflection took place. It has also been found that, when these spots were turned in a certain position, their surfaces appeared rough and uneven, a certain indication that they are not water. These circumstances, together with the fact that the moon's surface is never obscured by mist or vapour, arising from the evaporation of water from her surface, have induced astronomers to believe that the moon has neither seas, lakes, nor rivers, and indeed that no water exists there."

180. *Harvest moon; Hunters' moon.*—Twice in the year the moon rises almost at the same hour during a week. This occurs in September or October, and in March or April; in the former case, the moon is termed the *harvest moon*, in the latter, the *hunters' moon*. The following is an explanation of these phenomena, divested of technicalities. The moon moves

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179. What is said concerning the volcanoes of the moon? What is supposed concerning the lakes and seas of the moon? On what ground *is it supposed that* there is no water in the moon?—180. Explain the *phenomena of* the harvest moon and the hunters' moon.

nearly to the same distance from the sun every day, but it moves in a path the one-half of which is much nearer the north than the other; and this is the case also with the apparent annual path of the sun, that luminary appearing much nearer to the north in summer than in winter. Thus, when the moon is moving northward at the most rapid rate, it escapes from the horizon northward, and rises earlier; and when it moves southward at the most rapid rate, it approaches the horizon and sets earlier. The full moon can be in the former position only in September or October, and in the latter in March or April; and thus the *harvest* and *hunters'* moons are occasional.

THE SATELLITES.

181. *Satellites of Jupiter.*—It has already been stated that Jupiter is attended by four satellites. These, with their *primary* planet, constitute a miniature system, analogous, in the laws of its motions, to the great solar system in which the sun acts the part of primary, and the planets of satellites. The orbits of the satellites are ellipses of very moderate eccentricity, the primary occupying one focus. The eclipses of Jupiter's satellites, which happen very frequently, afford signals of considerable use for the determination of terrestrial longitudes. This method, indeed, until superseded by the greater exactness and facility now attainable by lunar observations, was the only one which could be relied on for great distances and long intervals. The following table, copied from Sir J. Herschel's Astronomy, exhibits a synoptical view of the distances and periods in this system, so far as they are at present known. The distances are expressed in equatorial radii of the primary. The epoch is January 1, 1801. The periods, &c., are expressed in mean solar days.

Sat.	Mean Distance.	Sidereal Revolution.	Inclination of Orbit to that of Jupiter.	Mass: that of Jupiter being 1000000000
1.	6·04853	$1^{d.}$ $18^{h.}$ $28^{m.}$	30° 5′ 30″	17328
2.	9·62347	3 13 14	Variable.	23235
3.	15·35024	7 3 43	Variable.	88497
4.	26·99835	16 16 32	2 58 48	42659

181. What kind of orbit is described by the satellites of Jupiter? To *what purpose has* the observation of their eclipses been subservient?

182. *Satellites of Herschel.*—Herschel is supposed to be attended by six satellites. Of these, two undoubtedly exist, and four have been suspected. "These two, however, offer remarkable, and indeed, quite unexpected and unexampled peculiarities. Contrary to the unbroken analogy of the whole planetary system—whether of primaries or secondaries—the planes of their orbits *are nearly perpendicular to the ecliptic*, being inclined no less than 78° 58′ to that plane, and in these orbits their motions *are retrograde;* that is to say, their positions, when projected on the ecliptic, instead of advancing *from west to east* round the centre of their primary, as is the case with every other planet and satellite, move in the opposite direction. Their orbits are nearly or quite circular, and they do not appear to have any sensible, or, at least, any rapid motion of nodes, or to have undergone any material change of inclination, in the course, at least, of half a revolution of their primary round the sun.

Sat.	Mean Distance.	Sidereal Period.	Inclination to Ecliptic.
1.?	13·120	5d. 21h. 25m. 0s.	Their orbits are inclined about 78° 58′ to the ecliptic, and their motion is retrograde. The periods of the second and fourth require a trifling correction. The orbits appear to be nearly circles.
2.	17·022	8 16 56 6	
3.?	19·845	10 23 4 0	
4.	22·752	13 11 8 59	
5.?	45·507	38 1 48 0	
6.?	91·008	107 16 40 0	

Sir J. Herschel's Astronomy.

183. *Satellites of Saturn.*—Saturn is attended by seven satellites. Of these, the most distant is by far the largest, and is probably not much inferior in size to Mars. Its orbit is also materially inclined to the plane of the ring, with which those of all the rest nearly coincide. The next in order (proceeding inwards) is tolerably conspicuous; the next three are very minute, and require a tolerably powerful telescope to see them; while the two interior, which just skirt the edge of the ring, and move exactly in its plane, require the

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182. What two peculiarities have been noticed in the satellites of Herschel? What is the form of their orbits?—183. With what degrees of distinctness *may the satellites of* Saturn be seen? What is the form *of their orbits?*

most powerful telescopes which have yet been constructed to view them. The following table is taken from the work of Sir John Herschel:—

Sat.	Mean Distance.	Sidereal Revolution.	Eccentricities and Inclinations.
1.	3·351	0d. 22h. 38m.	The orbits of the six interior satellites are nearly circular, and very nearly in the plane of the ring. That of the seventh is considerably inclined to the rest, and approaches nearer to coincidence with the ecliptic.
2.	4·300	1 8 53	
3.	5·284	1 21 18	
4.	6·819	2 17 45	
5.	9·524	4 12 25	
6.	22·081	15 22 41	
7.	64·359	79 7 55	

ECLIPSES.

184. "Every planet and satellite in the solar system is illuminated by the sun, and hence they cast shadows in the direction opposite to him, just as the shadow of a man reaches in a direction from the sun. A shadow is nothing more than the interception of the rays of light by an opaque body. The earth always makes a shadow, which reaches to an immense distance into open space, in the direction opposite to the sun. When the earth, turning on its axis, carries us out of the sphere of the sun's light, we say it is *sunset*, and then we pass into the earth's shadow, and night comes on. When the earth turns half round from this point, and we again emerge out of the earth's shadow, we say, the *sun rises*, and then day begins.

185. "Now an eclipse of the moon is nothing more than her falling into the shadow of the earth. The moon, having no light of her own, is thus darkened, and we say she is *eclipsed*. The shadow of the moon also reaches to a great distance from her. We know that it reaches at least 240,000 miles, because it sometimes reaches the earth. An eclipse of the sun is occasioned whenever the earth falls into the shadow of the moon. Hence, in eclipses, whether of the sun or moon, the

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184. What is a shadow? When do we say it is sunset, and when do we say it is sunrise?—185. What occasions an eclipse of the moon? *What causes* eclipses of the sun? In eclipses of the moon, what planet *is between the sun* and moon? In eclipses of the sun, what planet is *between the sun* and earth?

two planets and the sun must be nearly in a straight line with respect to each other. In eclipses of the moon, the earth is between the sun and moon, and in eclipses of the sun, the moon is between the earth and sun.

186. "If the moon went round the sun in the same plane with the earth, that is, were the moon's orbit on the plane of the ecliptic, there would happen an eclipse of the sun at every conjunction of the sun and moon, or at the time of every new moon. But at these conjunctions the moon does not come exactly between the earth and sun, because the orbit of the moon is inclined to the ecliptic at an angle of 5½ degrees. Did the planes of the orbits of the earth and moon coincide, there would be an eclipse of the moon at every full, for then the moon would pass exactly through the earth's shadow.

187. "One half of the moon's orbit being elevated 5½ degrees above the ecliptic, the other half is depressed as much below it, and thus the moon's orbit crosses that of the earth in two opposite points, called the moon's *nodes*. As the nodes of the moon are the points where she crosses the ecliptic, she must be half the time above, and the other half below these points. The node in which she crosses the plane of the ecliptic upward, or towards the north, is called her *ascending* node. That in which she crosses the same plane downward, or towards the south, is called her *descending* node.

188. "The moon's orbit, like those of the other planets, is elliptical, so that she is sometimes nearer the earth than at others. When she is at that part of her orbit which is at the greatest distance from the earth, she is said to be in her *apogee*, and when at her least distance from the earth, she is in her *perigee*.

189. "Eclipses can only happen at the time when the moon is at, or near, one of her *nodes*, for at no other time is she near the plane of the earth's orbit; and since the earth is always in this plane, the moon must be at, or near it, also, in order to bring the two planets and the sun in the same right line, without which no eclipse can happen.

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186. Why is there not an eclipse of the sun at every conjunction of the sun and moon? How many degrees is the moon's orbit inclined to that of the earth?—187. What are the nodes of the moon? What is meant by the ascending and descending nodes of the moon?—188. What is the moon's apogee, and what her perigee?—189. Why must the moon be at or near one of her nodes, to occasion an eclipse?

190. "The reason why eclipses do not happen oftener, and at regular periods, is because a node of the moon is usually only twice, and never more than three times in the year, presented towards the sun. The average number of total eclipses of both luminaries, in a century, is about thirty, and the average number of total and partial, in a year, about four. There may be seven eclipses in a year, including those of both luminaries, and there may be only two. When there are only two, they are both of the sun. When the moon is within 16½ degrees of her node, at the time of her change, she is so near the ecliptic, that the sun may be more or less eclipsed, and when she is within 12 degrees of her node, at the time of her full, the moon will be more or less eclipsed.

191. "But the moon is more frequently within 16½ degrees of her node at the time of her change, than she is within 12 degrees at the time of her full, and consequently there will be a greater number of solar, than of lunar eclipses, in a course of years. Yet more lunar eclipses will be visible, at any one place on the earth, than solar, because the sun, being so much larger than the earth, or moon, the shadow of these bodies must terminate in a point, and this point of the moon's shadow never covers but a small portion of the earth's surface, while lunar eclipses are visible over a whole hemisphere, and as the earth turns on its axis, are therefore visible to more than half the earth. This will be obvious by Figs. 28 and 29, where it will be observed that an eclipse of the moon may be seen wherever the moon is visible, while an eclipse of the sun will be total only to those who live within the space covered by the moon's dark shadow.

192. "LUNAR ECLIPSES.—When the moon falls into the shadow of the earth, the rays of the sun are intercepted, or hid from her, and she then becomes eclipsed. When the earth's shadow covers only a part of her face, as seen by us, she suffers only a *partial* eclipse, one part of her disk being obscured, while the other part reflects the sun's light. But when her whole surface is obscured by the earth's shadow, she then suffers a total eclipse, and of a duration proportion-

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190. Why do not eclipses happen often, and at regular periods? What is the greatest, and what the least number of eclipses that can happen in a year?—191. Why will there be more solar than lunar eclipses in the course of years? Why will more lunar than solar eclipses be visible at any one place?—192. Why is the same eclipse total at one place and only partial at another?

ate to the distance she passes through the earth's shadow. Fig. 28 represents a total lunar eclipse; the moon being in the midst of the earth's shadow. Now it will be apparent that in the situation of the sun, earth, and moon, as represented in the figure, this eclipse will be visible from all parts of that hemisphere of the earth which is next the moon, and that the moon's disk will be equally obscured, from whatever point it is seen. When the moon passes through only a part of the earth's shadow, then she suffers only a partial eclipse, but this is also visible from the whole hemisphere next the moon. It will be remembered that lunar eclipses happen only at full moon, the sun and moon being in opposition, and the earth between them.

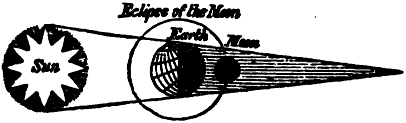

Fig. 28.

193. "Solar Eclipses.—When the moon passes between the earth and sun, there happens an eclipse of the sun, because then the moon's shadow falls upon the earth. A total eclipse of the sun happens often, but when it occurs, the total obscurity is confined to a small part of the earth; since the dark portion of the moon's shadow never exceeds 200 miles in diameter on the earth. But the moon's partial shadow, or *penumbra*, may cover a space on the earth of more than 4000 miles in diameter, within all which space the sun will be more or less eclipsed. When the penumbra first touches the earth, the eclipse begins at that place, and ends when the penumbra leaves it. But the eclipse will be

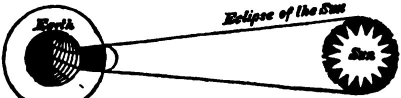

Fig. 29.

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193. Why is a total eclipse of the sun confined to so small a part of the earth? What is meant by penumbra? What will be the difference in the aspect of the eclipse, whether the observer stand within the dark *shadow, or only* within the penumbra?

total only where the dark shadow of the moon touches the earth. Fig. 29 represents an eclipse of the sun, without regard to the penumbra, that it may be observed how small a part of the earth the dark shadow of the moon covers. To those who live within the limits of this shadow, the eclipse will be total, while to those who live in any direction around it, and within reach of the penumbra, it will be only partial.

194. "Solar eclipses are called *annular*, from *annulus*, a ring, when the moon passes across the centre of the sun, hiding all his light, with the exception of a ring on his outer edge, which the moon is too small to cover from the position in which it is seen. Fig. 30 represents a solar eclipse, with the penumbra D C, and the *umbra*, or dark shadow, as seen in the above figure. When the moon is at its greatest distance from the earth, its shadow M O, sometimes terminates, before it reaches the earth, and then an observer standing directly under the point O, will see the outer edge of the sun, forming a bright ring around the circumference of the moon, thus forming an *annular* eclipse.

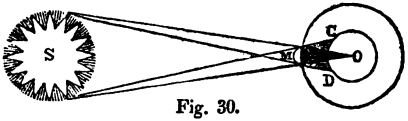

Fig. 30.

195. "The *penumbra* D C, is only a partial interception of the sun's rays, and in annular eclipses it is this partial shadow only which reaches the earth, while the umbra, or dark shadow, terminates in the air. Hence annular eclipses are never total in any part of the earth. The penumbra, as already stated, may cover more than 4000 miles of space, while the umbra never covers more than 200 miles in diameter; hence partial eclipses of the sun may be seen by a vast number of inhabitants, while comparatively few will witness the total eclipse.

196. "When there happens a total solar eclipse to us, we are eclipsed to the moon, and when the moon is eclipsed to us, an eclipse of the sun happens to the moon. To the moon,

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194. What is meant by annular eclipses?—195. Are annular eclipses *ever total* in any part of the earth? In annular eclipses, what part *of the moon's* shadow reaches the earth?—196. What is said concerning *the eclipses* of the earth, as seen from the moon?

an eclipse of the earth can never be total, since her shadow covers only a small portion of the earth's surface. Such an eclipse, therefore, at the moon, appears only as a dark spot on the face of the earth; but when the moon is eclipsed to us, the sun is partially eclipsed to the moon for several hours longer than the moon is eclipsed to us."

THE TIDES.

197. The ocean rises and falls alternately. Its depth is observed to be greatest at any given place at a certain time after the moon has passed the meridian of that place; it then decreases in depth to a certain degree, after which it again gradually rises. These phenomena recur after nearly the same intervals of time, and are called the *ebbing* and *flowing* of the ocean, or, more commonly, the *tides*. The interval of time between low water and the following high water is called *flood tide;* and that between high and low water, *ebb tide*. If the interval of time between two successive passages of the moon over the same semi-meridian be called a lunar day, there are generally, or on an average, two high tides in one lunar day.

198. "The cause of the tides is the attraction of the sun and moon, but chiefly of the moon, on the waters of the ocean. In virtue of the universal principle of gravitation, already explained, the moon, by her attraction, draws, or raises the water towards her; but, because the power of attraction diminishes as the squares of the distances increase, the waters, on the opposite side of the earth, are not so much attracted as they are on the side nearest the moon. This want of attraction, together with the greater centrifugal force of the earth on its opposite side, produced in consequence of its greater distance from the common centre of gravity, between the earth and moon, causes the waters to rise on the opposite side, at the same time that they are raised by direct attraction on the side nearest the moon.

199. "Thus the waters are constantly elevated on the

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197. What are the tides? What are flood tide and ebb tide?—198. What is the cause of the tides? What causes the tide to rise on the side of the earth opposite to the moon?—199. If the earth stood still, the tides would rise only as the moon passes round the earth; what then causes the tides to rise twice in 24 hours? When it is high water under the moon by her attraction, what is the cause of high water on the opposite side of the earth at the same time?

sides of the earth opposite to each other above their common level, and consequently depressed at opposite points equally distant from these elevations. Let M, Fig. 31, be the moon, and E the earth covered with water. 1. As the moon passes round the earth, its solid and fluid parts are equally attracted by her influence according to their densities; but while the solid parts are at liberty to move only as a whole, the water obeys the slightest impulse, and thus tends towards the moon where her attraction is the strongest. Consequently, the waters are perpetually elevated immediately under the moon. If, therefore, the earth stood still, the influence of the moon's attraction would raise the tides only as she passed round the earth. 2. But as the earth turns on her axis every 24 hours, and as the waters nearest the moon, as at A, are constantly elevated, they will, in the course of 24 hours, move round the whole earth, and consequently from this cause there will be high water at every place once in 24 hours. 3. As the elevation of the waters under the moon causes their depression at 90 degrees' distance on the opposite sides of the earth, D and C, the point C will come to the same place, by the earth's diurnal revolution, six hours after the point A, because C is one quarter of the circumference of the earth from the point A, and therefore there will be low water at any given place six hours after it was high water at that place. 4. But while it is high water under the moon, in consequence of her direct attraction, it is also high water on the opposite side of the earth, in consequence of her diminished attraction and the earth's centrifugal motion, and therefore it will be high water from this cause twelve hours after it was high water from the former cause, and six hours after it was low water from both causes.

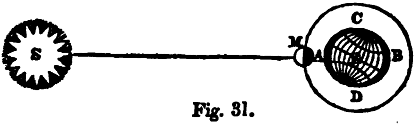

Fig. 31.

200. "Thus when it is high water at A and B, it is low water at C and D, and as the earth revolves once in 24 hours, there will be an alternate ebbing and flowing of the tide, at every place, once in six hours. But while the earth turns

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200. Why are the tides about 50 minutes later every day?

on her axis, the moon advances in her orbit, and consequently any given point on the earth will not come under the moon on one day so soon as it did on the day before. For this reason, high or low water at any place occurs about fifty minutes later on one day than it did the day before.

201. "Thus far we have considered no other attractive influence except that of the moon, as affecting the waters of the ocean. But the sun, as already observed, has an effect upon the tides, though on account of his great distance, his influence is small when compared with that of the moon. When the sun and moon are in conjunction, as represented in Fig. 31, which takes place at her change, or when they are in opposition, which takes place at full moon, then their forces are united, or act on the waters in the same direction, and consequently the tides are elevated higher than usual, and on this account are called *spring tides*.

202. "But when the moon is in her quadratures, or quarters, the attraction of the sun tends to counteract that of the moon, and although his attraction does not elevate the waters and produce tides, his influence diminishes that of the moon, and consequently the elevation of the waters is less when the sun and moon are so situated in respect to each other, than when they are in conjunction, or opposition. This effect is represented by Fig. 32, where the elevation of the tides at C and D is produced by the causes already explained; but their elevation is not so great as in Fig. 31, since the influence of the sun acting in the direction A B, tends to counteract the moon's attractive influence. These small tides are called *neap tides*, and happen only when the moon is in her quadratures.

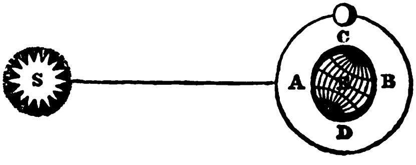

Fig. 32.

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201. What produces spring tides? Where must the moon be in respect to the sun to produce spring tides?—202. What is the occasion of neap tides?

203. "The tides are not at their greatest heights at the time when the moon is at its meridian, but some time afterwards, because the water, having a motion forward, continues to advance by its own inertia, some time after the direct influence of the moon has ceased to affect it." This may be also observed with respect to the greatest heat and cold, which are not felt on the solstitial days, when the action of the sun is greatest and least.

204. The tides rise to different heights in different parts of the world; in the Bristol channel they rise above forty feet, and on the eastern coast of North America more than fifty feet; but their average height is considerably under twenty feet. In the Mediterranean sea, the tides are small, and in some places scarcely perceptible; this is occasioned by the inland character of that sea, and by the arrest given to the rise and fall of the tides by the straits of Gibraltar.

LATITUDE AND LONGITUDE.

205. The situation of places on the surface of the earth* is determined, as to north or south, by their *latitude*, and as to east and west, by their *longitude;* and these distances are reckoned by *degrees*, *minutes*, and *seconds*. Every circle, whatever may be its diameter, is divided into 360 degrees—a mode of division suggested by the supposed passage of the sun through the ecliptic, or great circle of the heavens, in 360 days, each day's progress being termed a *gradus*, step or degree. Each degree is subdivided into 60 minutes, or miles, and each minute into 60 seconds. These divisions are denoted by the signs °, ′, ″; thus 55°, 34′, 23″, signify 55 degrees, 34 minutes or miles, and 23 seconds. Further, N. stands for north, S. for south latitude; E. for east, W. for west longitude.

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203. Why are not the tides at their greatest height when the moon is at its meridian?—204. What is the average height of tides? State some exceptions to this rule.—205. How is the situation of places on the surface of the earth determined, as to north and south? How, as to east and west? How is a circle divided? What are the signs of the divisions?

* The surface of the earth comprises 148,187,500 square miles, of which about one-fourth part, or 39,956,500 square miles, is land, and the remaining three-fourths, or 108,231,000 square miles, are water. The estimated number of square miles contained in each quarter of the globe, is as follows:—

	Square Miles.		Square Miles.
Europe,	2,635,700	*Africa*,	8,902,000
Asia,	15,526,300	America,	12,892,000

206. The mile of which we have here spoken, is the *geographical mile*, and must not be confounded with the *British statute mile*, or the common itinerary measure of this country, and of which 69⅛ are contained in a degree of latitude. The former is, however, always understood to be employed, unless the latter be specified.

207. "*Latitude* is the distance from the equator in a direct line, north or south, measured in degrees and minutes. The number of degrees is 90 north, and as many south, each line on which these degrees are reckoned running from the equator to the poles. Places on the north of the equator are in *north latitude*, and those on the south of the equator are in *south latitude*. The *parallels* of latitude are imaginary lines drawn parallel to the equator, either north or south, and hence every place situated on the same parallel is in the same latitude, because every such place must be at the same distance from the equator. The length of a degree of latitude is 60 geographical miles.

208. "*Longitude* is the distance measured in degrees and minutes, either east or west, from any given point on the equator, or on any parallel of latitude. Hence the lines, or meridians of longitude, cross those of latitude at right angles. The degrees of longitude are 180 in number, its lines extending half a circle to the east, and half a circle to the west, from any given meridian, so as to include the whole circumference of the earth. A degree of longitude, at the equator, is of the same length as a degree of latitude, but as the poles are approached, the degrees of longitude diminish in length, because the earth grows smaller in circumference from the equator towards the poles; hence the lines surrounding it become less and less.

209. "This will be made obvious by Fig. 33. Let this figure represent the earth, N being the north pole, S the south pole, and E W the equator. The lines 10, 20, 30, and so on, are the parallels of latitude, and the lines N A S, N B S, &c., are meridian lines, or those of longi-

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206. What is the difference between a geographical mile and a British statute mile?—207. What is latitude? How many degrees of latitude are there? How far do the lines of latitude extend? What is meant by north and south latitude? What are the parallels of latitude?—208. What is longitude? How many degrees of longitude are there, east or west? What is the latitude of any place?—209. What is the *longitude of a place?*

tude. The latitude of any place on the globe, is the number of degrees between that place and the equator, measured on a meridian line; thus, x is in latitude 40 degrees, because the x G part of the meridian contains 40 degrees. The longitude of a place is the number of degrees it is situated east or west from any meridian line; thus, v is 20 degrees west longitude from x, and x is 20 degrees east longitude from v.

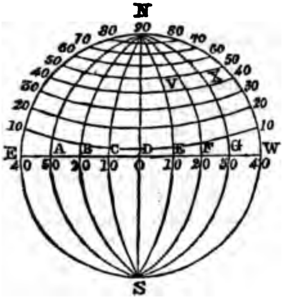

Fig. 33.

210. "As the equator divides the earth into two equal parts, or hemispheres, there seems to be a natural reason why the degrees of latitude should be reckoned from this great circle. But from east to west there is no natural division of the earth, each meridian line being a great circle, dividing the earth into two hemispheres, and hence there is no natural reason why longitude should be reckoned from one meridian any more than another. It has, therefore, been customary for writers and mariners to reckon longitude from the capital of their own country, as the English from London, the French from Paris, and the Americans from Washington. But this mode, it is apparent, must occasion much confusion, since each writer of a different nation would be obliged to correct the longitude of all other countries, to make it agree with his own. More recently, therefore, the writers of Europe and America have selected the royal observatory, at Greenwich, near London, as the first meridian, and on most maps and charts lately published, longitude is reckoned from that place.

211. "*How latitude is found.*—The latitude of any place

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210. Why are the degrees of latitude reckoned from the equator? What is said concerning the places from which the degrees of longitude have been reckoned? What is the inconvenience of estimating longitude from a place in each country? From what place is longitude reckoned in Europe and America?—211. How is the latitude of a place determined? Give an example of the method of finding the latitude of the same place at different seasons of the year.

is determined by taking the altitude of the sun at mid-day, and then subtracting this from 90 degrees, making proper allowances for the sun's place in the heavens. The reason of this will be understood, when it is considered that the whole number of degrees from the zenith to the horizon is 90, and therefore if we ascertain the sun's distance from the horizon, that is, his altitude, by allowing for the sun's declination north or south of the equator, and subtracting this from the whole number, the latitude of the place will be found. Thus, suppose that on the 20th of March, when the sun is at the equator, his altitude from any place north of the equator should be found to be 48 degrees above the horizon; this, subtracted from 90, the whole number of the degrees of latitude, leaves 42, which will be the latitude of the place where the observation was made.

212. "If the sun, at the time of observation, has a declination north or south of the equator, this declination must be added to, or subtracted from, the meridian altitude, as the case may be. For instance, another observation being taken at the place where the latitude was found to be 42, when the sun had a declination of 8 degrees north, then his altitude would be 8 degrees greater than before, and therefore 56, instead of 48. Now, subtracting this 8, the sun's declination, from 56, and the remainder from 90, the latitude of the place will be found 42, as before. If the sun's declination be south of the equator, and the latitude of the place north, his declination must be added to the meridian altitude, instead of being subtracted from it. The same result may be obtained by taking the meridian altitude of any of the fixed stars, whose declinations are known, instead of the sun's, and proceeding as above directed.

213. "*How longitude is found.*—There is more difficulty in ascertaining the degrees of longitude, than those of latitude, because, as above stated, there is no fixed point, like that of the equator, from which its degrees are reckoned. The degrees of longitude are therefore estimated from Greenwich, and are ascertained by the following methods:—

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212. When must the sun's declination from the equator be added to, and when subtracted from, his meridian altitude?—213. Why is there more difficulty in ascertaining the degrees of longitude than of latitude?

214. "When the sun comes to the meridian of any place, it is noon, or 12 o'clock, at that place, and therefore, since the equator is divided into 360 equal parts, or degrees, and since the earth turns on its axis once in 24 hours, 15 degrees of the equator will correspond with one hour of time, for 360 degrees being divided by 24 hours, will give 15. The earth, therefore, moves in her daily revolution, at the rate of 15 degrees for every hour of time. Now, as the apparent course of the sun is from east to west, it is obvious that he will come to any meridian lying east of a given place, sooner than to one lying west of that place, and therefore it will be 12 o'clock to the east of any place, sooner than at that place, or to the west of it. When, therefore, it is noon at any one place, it will be 1 o'clock at all places 15 degrees to the east of it, because the sun was at the meridian of such places an hour before; and so, on the contrary, it will be eleven o'clock, fifteen degrees west of the same place, because the sun has still an hour to travel before he reach the meridian of that place. It makes no difference, then, where the observer is placed, since, if it is 12 o'clock where he is, it will be 1 o'clock 15 degrees to the east of him, and 11 o'clock 15 degrees to the west of him, and so in this proportion, let the time be more or less. Now, if any celestial phenomenon should happen, such as an eclipse of the moon, or of Jupiter's satellites, the difference of longitude between two places where it is observed, may be determined by the difference of the times at which it appeared to take place. Thus, if the moon enters the earth's shadow at 6 o'clock in the evening, as seen at Philadelphia, and at half past 6 o'clock at another place, then this place is half an hour, or 7½ degrees, to the east of Philadelphia, because 7½ degrees of longitude are equal to half an hour of time. To apply these observations practically, it is only necessary that it should be known exactly at what time the eclipse takes place at a given point on the earth.

215. "Longitude is also ascertained by means of a chronometer, or true time-piece, adjusted to any given meridian; for if the difference between two clocks, situated east and

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214. How many degrees of longitude does the surface of the earth pass through in an hour? Suppose it is noon at any given place, what o'clock will it be 15 degrees to the east of that place? Explain the *reason. How may longitude be determined by an eclipse?*—215. *Explain the principles* on which longitude is determined by the *chronometer.*

west of each other, and going exactly at the same rate, can be known at the same time, then the distance between the two meridians, where the clocks are placed, will be known, and the difference of longitude may be found.

216. "Suppose two chronometers, which are known to go at exactly the same rate, are made to indicate 12 o'clock by the meridian line of Greenwich, and the one be taken to sea, while the other remains at Greenwich. Then suppose the captain, who takes his chronometer to sea, has occasion to know his longitude. In the first place, he ascertains, by an observation of the sun, when it is 12 o'clock at the place where he is, and then by his time-piece, when it is 12 o'clock at Greenwich, and by allowing 15 degrees for every hour of the difference in time, he will know his precise longitude in any part of the world. For example, suppose the captain sails with his chronometer for America, and after being several weeks at sea, finds by observation that it is 12 o'clock by the sun, and at the same time finds by his chronometer that it is 4 o'clock at Greenwich. Then because it is noon at his place of observation after it is noon at Greenwich, he knows that his longitude is west from Greenwich, and by allowing 15 degrees for every hour of the difference, his longitude is ascertained. Thus, 15 degrees, multiplied by 4 hours, give 60 degrees of west longitude from Greenwich. If it is noon at the place of observation, before it is noon at Greenwich, then the captain knows that his longitude is east, and his true place is found in the same manner."

THE FIXED STARS.

217. Besides the bodies which have been described, an innumerable multitude of luminaries, which have not been observed to change their places with respect to each other, may be seen in the heavens. These are termed *fixed stars*, not because it is absolutely denied that they are in a state of motion, but because their motion, if any, is exceedingly slow, and inappreciable by us, in consequence of the stupendous distances at which they are placed from our system. The

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216. Suppose the captain finds by his chronometer that it is twelve o'clock, where he is, six hours later than at Greenwich, what then would be his longitude? Suppose he finds it to be twelve o'clock four hours earlier, where he is, than at Greenwich, what then would be his longitude?—217. Why are the stars called fixed? How may the stars be distinguished from the planets

fixed stars may be distinguished from the planets by their scintillations or twinkling.

218. *Classification of fixed stars.*—The fixed stars have been classified, according to their comparative brightness, into stars of the first, second, and so on to the sixth or seventh *magnitude.* 1. By the use of powerful instruments, this mode of distribution has been extended to stars of the sixteenth magnitude, and would probably admit of unlimited application, if our instruments were susceptible of adequate improvement. About 15 or 20 stars are usually referred by astronomers to the first magnitude; from 50 to 60 to the second; about 200 to the third; and so on, according to their decreasing brightness, including a catalogue of nearly 20,000 stars, which have been reckoned down to the seventh magnitude. It was observed by Kepler that the surface of a sphere presents only thirteen points equally distant from each other, and from the centre; hence, supposing that the nearest fixed stars are as distant from each other as they are from the sun, he concludes that there are only thirteen stars of the first magnitude. At twice the distance from the sun, there may be four times as many, or fifty-two stars of the second magnitude; and so on. This ingenious suggestion indicates, with tolerable accuracy, the number of stars usually referred to first, second, and third magnitude.

219. *Distances of the fixed stars.*—"The nearest fixed stars to our system, from the most accurate astronomical calculations, cannot be nearer than 20,000,000,000,000, or 20 trillions of miles from the earth, a distance so immense, that light cannot pass through it in less than three years. Hence, were these stars annihilated at the present time, their light would continue to flow towards us, and they would appear to be in the same situation to us, three years hence, that they do now. Our sun, seen from the distance of the nearest fixed stars, would appear no larger than a star of the first

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218. The stars are divided into classes according to their magnitudes; how many classes are there? How many stars may be seen with the naked eye in the whole firmament? State the suggestion of Kepler with reference to the classification of the stars.—219. What is the computed distance of the nearest fixed stars from the earth? How long would it take light to reach us from the fixed stars? How large would our sun appear at the distance of the fixed stars? What is *said concerning the* difference of the distance between the earth and the *fixed stars at different* seasons of the year, and of their different appear*ance in consequence?*

magnitude does to us. These stars appear no larger to us, when the earth is in that part of her orbit nearest to them, than they do when she is in the opposite part of her orbit; and as our distance from the sun is 95,000,000 of miles, we must be twice this distance, or the whole diameter of the earth's orbit, nearer a given fixed star at one period of the year than at another. The difference, therefore, of 190,000,000 of miles, bears so small a proportion to the whole distance between us and the fixed stars, as to make no appreciable difference in their sizes, even when assisted by the most powerful telescopes.

220. "The amazing distances of the fixed stars may also be inferred from the return of comets to our system, after an absence of several hundred years. The velocity with which some of these bodies move, when nearest the sun, has been computed at nearly a million of miles in an hour, and although their velocities must be perpetually retarded, as they recede from the sun, still, in 250 years of time, they must move through a space which to us would be infinite. The periodical return of one comet is known to be upwards of 500 years, making more than 250 years in performing its journey to the most remote part of its orbit, and as many in returning back to our system; and that it must still always be nearer our system than the fixed stars, is proved by its return; for by the laws of gravitation, did it approach nearer another system it would never again return to ours.

221. "From such proofs of the vast distances of the fixed stars, there can be no doubt that they shine with their own light, like our sun, and hence the conclusion that they are suns to other worlds, which move around them, as the planets do around our sun. Their distances will, however, prevent our ever knowing, except by conjecture, whether this is the case or not, since, were they millions of times nearer us than they are, we should not be able to discover the reflected light of their planets."

222. *Milky way.*—"There are not wanting," observes Sir J. Herschel, "*natural* districts in the heavens, which offer great peculiarities of character, and strike every observer: such is the *milky way*, that great luminous band,

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220. How may the distances of the fixed stars be inferred by the long absence and return of comets?—221. On what grounds is it supposed that the fixed stars are suns to other worlds?—222. What is the *milky way?* How is it divided?

which stretches, every evening, all across the sky, from horizon to horizon, and which, when traced with diligence, and mapped down, is found to form a zone completely encircling *the whole sphere*, almost in a great circle, which is neither an *hour* circle, nor coincident with any other of our astronomical *grammata*. It is divided in one part of its course, sending off a kind of branch, which unites again with the main body, after remaining distinct for about 150 degrees. This remarkable belt has maintained, from the earliest ages, the same relative situation among the stars; and, when examined through powerful telescopes, is found (wonderful to relate) *to consist entirely of stars scattered by millions*, like glittering dust, on the black ground of the general heavens.

223. *Periodical stars.*—"Among the stars are several which, though no way distinguishable from others by any apparent change of place, nor by any difference of appearance in telescopes, yet undergo a regular periodical increase and diminution of lustre, involving, in one or two cases, a complete extinction and revival. These are called *periodical stars*. One of the most remarkable is the star *Omicron*, in the constellation *Cetus*, first noticed by Fabricius in 1596. It appears about twelve times in eleven years, or more exactly, in a period of 334 days; remains at its greatest brightness about a fortnight, being then, on some occasions, equal to a large star of the second magnitude; decreases during about three months, till it becomes completely invisible, in which state it remains during about five months, when it again becomes visible, and continues increasing during the remaining three months of its period."—*Herschel's Astronomy.*

224. *Temporary stars.*—Sir J. Herschel describes other phenomena of stellar variation, under the term of *temporary stars*, which have appeared, from time to time, in different parts of the heavens, blazing forth with extraordinary lustre; and, after remaining a while apparently immoveable, have died away and left no trace. The appearance of a star of this kind, in 1572, was so sudden, that Tycho Brahe, returning one evening (Nov. 11) from his laboratory to his dwelling-house, was surprised to find a group of country people gazing at a star, which he was sure did not exist half an hour before. It was then as bright as Sirius, and continued to

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223. *What* are periodical stars? Describe the periodicity of one of *these.*—*224.* What are temporary stars? Give an account of one of *these.*

increase till it surpassed Jupiter when brightest, and was visible at mid-day. It began to diminish in December of the same year, and in March, 1574, had entirely disappeared. So, also, on the 10th of October, 1604, a star of this kind, and not less brilliant, burst forth in the constellation of Serpentarius, and continued visible till October, 1605.

COMETS.

225. "Besides the planets which move round the sun in regular order, and in nearly circular orbits, there belongs to the solar system an unknown number of bodies called *comets*, (or *hairy stars*,) which move round the sun in orbits exceedingly eccentric, or elliptical, and whose appearance among our heavenly bodies is only occasional. Comets, to the naked eye, have no visible disk, but shine with a faint, glimmering light, and are accompanied by a *train* or *tail*, turned from the sun, and which is sometimes of immense length. They appear in every region of the heavens, and move in every possible direction.

226. "It had been supposed that comets moved in straight lines, coming from the regions of infinite, or unknown space, and merely passing by our system, on their way to regions equally unknown and infinite, and from which they never returned. Sir Isaac Newton was the first to demonstrate that the comets pass round the sun, like the planets, but that their orbits are exceedingly elliptical, and extend out to a vast distance beyond the solar system.

227. "The number of comets is unknown, though some astronomers suppose that there are nearly 500 belonging to our system. Ferguson, who wrote in about 1760, supposed that there were fewer than 30 comets which made us occasional visits; but since that period the elements of the orbits of nearly 100 of these bodies have been computed. Of these, however, there are only three whose periods of return among us are known with any degree of certainty. The first of these has a period of 75 years; the second a period of 129 years; and the third a period of 575 years. The third appeared

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225. What is a comet?—226. In what kind of orbit do comets move?—227. What number of comets are supposed to belong to our system? How many have had the elements of their orbits estimated by astronomers? How many are there whose periods of return are known? *What is said of* the comet of 1682?

in 1682, and therefore cannot be expected again until the year 2257. This comet, Fig. 34, in 1682, excited the most intense interest among the astronomers of Europe, on account of its great apparent size, and near approach to our system. In the most remote part of its orbit, its distance from the sun was estimated at about eleven thousand two hundred millions of miles. At its nearest approach to the sun, which was only about 50,000 miles, its velocity, according to Sir Isaac Newton, was 880,000 miles in an hour; and supposing it to have retained the sun's heat, like other solid bodies, its temperature must have been about 2000 times that of red hot iron. The tail of this comet was at least 100 millions of miles long.

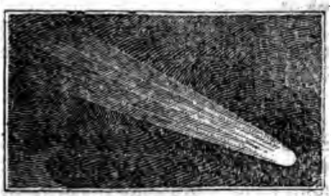

Fig. 34.

228. "In the Edinburgh Encyclopedia, article *Astronomy*, there is the most complete table of comets yet published. This table contains the elements of 97 comets, calculated by different astronomers, down to the year 1808. From this table it appears that 24 comets have passed between the sun and the orbit of Mercury; 33 between the orbits of Venus and the Earth; 15 between the orbits of the Earth and Mars; 3 between the orbits of Mars and Ceres; and 1 between the orbits of Ceres and Jupiter. It also appears by this table that 49 comets have moved round the sun from west to east, and 48 from east to west.

229. "Of the nature of these wandering planets very little is known. When examined by a telescope, they appear like a mass of vapours surrounding a dark nucleus. When the comet is at its perihelion, or nearest the sun, its colour seems to be heightened by the intense light or heat of that luminary, and it then often shines with more brilliancy than the planets. At this time the *tail* or *train*, which is always directly opposite to the sun, appears at its greatest length, but is commonly so transparent as to permit the fixed stars to be seen through

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228. How many comets are described as moving round the sun from *west to east,* and how many from east to west?—229. What is the *general appearance* presented by a comet? What opinions have been *entertained of their* nature?

it. A variety of opinions have been advanced by astronomers concerning the nature and causes of these trains. Newton supposed that they were thin vapour, made to ascend by the sun's heat, as the smoke of a fire ascends from the earth; while Kepler maintained that it was the atmosphere of the comet driven behind it by the impulse of the sun's rays. Others suppose that this appearance arises from streams of electric matter passing away from the comet," &c.

230. The comet, above noticed (§ 227), has been named from Edmund Halley, who considered it the same as that which had appeared in 1531 and 1607. He, accordingly, *predicted* its reappearance about the year 1759, and on the 12th of March in that year it actually re-appeared. This is the first comet whose *periodicity* was foretold, and the truth of the prediction verified. Its next return to the perihelion was calculated by M. Damoiseau, and fixed for the year 1835. The intervals of its returns are therefore 75 or 76 years. The comet named from Prof. Encke, of Berlin, completes its orbit in about 3⅓ years. Its return was calculated in 1819, and the result of the calculation verified by its several reappearances in 1822, 1825, 1828, &c. The comet of Biela is identical with that which appeared in 1789, 1795, &c. It describes its elliptic orbit about the sun in 6¾ years, and was seen in 1832 and 1838. The periods of this comet are continually diminishing; in other words, its mean distance from the sun, or the major axis of the ellipse, are dwindling by slow but regular degrees.

231. The probability of a comet coming in collision with the earth, or with any other planet, may be reduced to a very slight amount, if we compare with the small volume of the earth or any other planet, and that of comets, the immensity of the space in which these bodies move. M. Arago observes that the doctrine of chances affords us the means of estimating numerically the probability of such a collision, and shows that there is but one such chance in 281 millions; that is to say, that, on the appearance of a new comet, the odds are 281 millions to one that it will *not* strike against one globe.

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230. State the periodicities of the comets of Halley, Encke, and Biela.—231. What is the amount of probability that a comet will ever come into collision with the earth?

APPENDIX.

Artificial globes are instruments generally employed for the purpose of conveying to students the first ideas of the figure and rotation of the earth, of latitude and longitude, and of the situation of places with respect to each other, and to the sun at the different seasons of the year. The artificial globe is formed of metal or plaster, on the surface of which is delineated a map of the earth, or of the celestial constellations, together with the principal circles of the sphere; in the former case, the instrument is called a *terrestrial;* in the latter, a *celestial globe.* These globes are also used for the purpose of solving mechanically a few elementary problems of astronomy, relative to the difference of the hour of the day at different places, the times of the rising and setting of the sun, the limits of the visibility of eclipses, &c.

The use of the *celestial* globe, must, however, be limited to general explanation, for, it is evident, that the *convex* surface of such a globe must fail to afford correct notions of the actual state of things in the apparently *concave* surface of the heavens. In order to understand the use of this instrument, the eye of the observer must be supposed to be placed in the centre, and its glance directed to the surface; each star will then appear in a position corresponding to that which it occupies to an observer standing on the surface of the earth. Or a small terrestrial globe may be imagined to be placed within the celestial, with their axes coinciding. Some of the universities of Europe are furnished with celestial globes of sufficient magnitude to admit several persons within, the celestial bodies and the circles being painted on the inner surface. By the revolution of this sphere, the spectators within observe the stars to rise and set, as in the real hemisphere. Occasionally, the celestial globe has been made of glass, and a terrestrial globe placed within it, capable of revolving from west to east, by means of machinery; the motion of the earth and the apparent diurnal motion of the heavens are thus sufficiently illustrated for general purposes.

The *terrestrial* globe is obviously an instrument of greater practical utility. Let the student, before he applies his mind to the following problems, make himself thoroughly acquainted with the circles of the artificial globe, by reference to the explanations already given in this work.

PROBLEM I.—*To determine the position of the meridian of the place of observation.*

"This may be done roughly, but sufficiently accurately for our present purpose, in the following simple manner:—Erect a stick in the ground, taking care, by applying a plumb-line, that it be quite perpendicular; observe the length of its shadow on a sunny morning at eight or nine o'clock; and, with this line for a radius, describe a circle round the stick, marking the exact point where the shadow touched it; about three or four o'clock in the afternoon, the shadow will reach the circle on the opposite side; mark the point as before. If now you bisect the arc between the two points, and draw a line from the point of bisection to the end of the stick, this will be a due north and south, or *meridian* line, and on it, at noon, the shadow of the stick will always fall. If this observation be taken within a week before or after midsummer, it will be sufficiently accurate to determine the solar noon throughout the year."—*Drew's Manual of Astronomy.*

PROBLEMS ON THE TERRESTRIAL GLOBE.

PROBLEM II.—*To find the latitude and longitude of any given place.*

Find the given place on the globe, and bring it to the graduated edge of the brazen meridian. Then, the degree on this meridian, immediately over the place, will be the latitude sought; and the degree on the equator, which corresponds with the graduated edge of the brazen meridian, will be the longitude of the given place.

Note.—If the latitude is north of the equator, it is called north latitude; if south of the equator, it is called south latitude. If the longitude is east of the first meridian, it is called east longitude; if west of the first meridian, it is called west longitude.

Find the latitude and longitude of the island of St Helena; of Gibraltar; of Mexico; of Calcutta; of Nankin; of Cape Horn; and of Philadelphia. What place has no latitude or longitude?

PROBLEM III.—*To find the difference in latitude between any two given places.*

Bring the places successively to the meridian, and note the latitude of each. If the latitudes thus found, be both north, or both south, subtract the less from the greater, and the remainder is the difference between them; if one of them be in north, and the other in south latitude, add them together, and their sum is the difference required.

What is the difference between the latitudes of London and Rome? Between those of Constantinople and Cape Horn? Between those of Canton and Paris? Between those of New York and Valparaiso? Between those of Archangel and St Petersburgh? Between those of Portland and St Salvador?

PROBLEM IV.—*To find the difference in longitude between any two given places.*

Find the longitude of each place, subtracting the less from the greater, if they be both in east, or both in west longitude, and the remainder will be the difference required. If one place be in east, and the other in west longitude, add them together, and the product will be the difference required.

What is the difference of longitude between London and Washington? Between Cork and Adrianople? Between Cadiz and Berlin? Between Boston and Rome? Between Warsaw and Dublin? Between Oporto and Bourdeaux? Between Copenhagen and Astrachan?

PROBLEM V.—*To find a place when the latitude and longitude are given.*

Look on the equator for the given longitude, and bring it to the brazen meridian. Then find the given latitude on the meridian, and directly under it is the place required.

What city is situated 30° east longitude, and 31° north latitude? What island lies 6° west longitude, and 16° south latitude? What city is situated 116° east longitude, and 40° north latitude? What island lies 63° west longitude, and between 32° and 33° north latitude?

PROBLEM VI.—*Method of rectifying the globe to the latitude, to the zenith, and to the sun's place.*

Elevate the pole above the horizon, till its altitude is equal to the latitude of the place. If the place is in north latitude, the north pole is to be elevated; if it is in south latitude, the south pole is to be elevated. When this is done, fix the quadrant of altitude* on the brazen meridian, at the zenith, which is directly over the latitude of the place. The globe should also be placed so that the poles may stand due north and south, corresponding with the poles of the earth.

The globe having been thus rectified to the latitude and the zenith, let the given day of the month be found in the outer circle of the wooden horizon, and against it, in the middle circle, is the sun's place in the ecliptic. Then find the same sign and degree in the ecliptic, bringing it to that part of the meridian numbered from the equator to the poles; at the same time putting 12 on the hour circle to the said meridian. The globe is now rectified as required.

Examples for practice.—Let the globe be rectified for New York on the 15th of May. New York being about 40° north, the north pole must be raised 40° above the horizon, and the quadrant of altitude fastened directly over the latitude. Then find on the horizon the 15th of May, which answers to the 20th of Taurus. This being done, bring the 20th of Taurus on the ecliptic, to the meridian, and set the index to the hour circle at 12, and the globe is rectified. For the latitude and zenith of all other places, the globe may be rectified in the same way. From a similar examination of the horizon to the globe, it will be seen that the 1st of June corresponds to the 10th of Gemini; the 10th of August to the 18th of Leo; and the 15th of April to the 26th of Aries.

How is the globe rectified to the latitude of a place? How, to the zenith? How, to the sun's place? Where is the sun's place on the ecliptic on the 5th of July? On the 12th of January? On the 25th of December? On the 14th of September? On the 20th of May? On the 4th of April? On the 22d of November?

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* The *quadrant of altitude* is an appendix to an artificial globe, consisting of a thin pliable slip of brass, which is applied to the globe, and used as a scale for measuring the distances between points in degrees. It is graduated in to 90°, the degrees being of the same length as those on one of the great circles of the globe. At the end where the division terminates, a nut is riveted on, and furnished with a screw, by which it is attached to the brass meridian of the globe at any point. This point being placed in the zenith, and the quadrant applied to the globe, its zero coincides with the horizon; and consequently the altitude of any point along its graduated edge is indicated by the corresponding division.

PROBLEM VII.—*To find the distance between any two given places.*

Bring one of the places to the brazen meridian, over which fix the quadrant of altitude; then extend it over the other place, and the number of degrees on the quadrant contained between, is the distance in degrees. This being done, multiply the number of degrees by 69½, and the product will be the number of English miles. If multiplied by 60, the product will be the number of geographical miles.

What is the distance in English miles between London and Paris? Between Vienna and Rome? Between Philadelphia and Savannah? Between Pekin and Constantinople? Between Berlin and Madrid? Between Calcutta and Canton? Between New York and Montreal?

PROBLEM VIII.—*To find the hour of the day at a required place, when the day and hour of another place are given.*

Bring the given place to the meridian, set the index to the given hour, then turn the globe till the required place comes under the meridian, and the index will point out what the hour is at that place. Thus, when it is 12 o'clock at noon in London, it is 7 o'clock in the morning at Philadelphia, and 4 o'clock in the afternoon at the island of Mauritius.

When it is noon at London, what is the hour at Constantinople? When it is noon at St Petersburgh, what is the hour at New York? When it is noon at Rome, what is the hour at Canton? When it is noon at Quebec, what is the hour at the mouth of the Columbia river? At Washington, when it is 6 o'clock in the evening, where is it noon?

PROBLEM IX.—*To find at what hour the sun rises and sets, and the length of the day and night, at any place, on any given day of the year.*

Find the latitude of the place, and rectify the globe for the latitude; find the sun's place in the ecliptic, bring it to the brazen meridian, and set the index of the hour circle at the upper 12; turn the globe on its axis eastward until the sun's place is level with the horizon, and the index will point to the hour of the sun's rising. Turn the globe on its axis westward, until the sun's place is level with the western edge of the horizon, and the index will point to the hour of the sun's setting.

The *hour* of the sun's rising being doubled, shows the length of the night; and the hour of the sun's setting being doubled, shows the length of the day.

At what time will the sun rise and set in London on the 22d of June? And what will be the length of the day and night? At what time will the sun rise and set at St Petersburgh on the 10th of January? And what will be the length of the day and night? At what time will the sun rise and set at New York on the 20th of December? And what will be the length of the day and night?

PROBLEM X.—*To find those days of the year on which the sun will be vertical at any given place in the torrid zone.*

Bring the given place to the brazen meridian, and mark its latitude; then turn the globe on its axis, and observe those two points of the ecliptic which pass under that degree of latitude; look for those points of the ecliptic, in the circle of signs on the horizon, against which, in the circle of months, are the days required?

When will the sun be vertical at Calcutta? At Sierra Leone? At Mexico? At Canton? At St. Helena? At Havannah? At the Sandwich Islands? At the Friendly Islands?

PROBLEM XI.—*To find all those places on the globe which will have a vertical sun, the month and the day of the month being given.*

Find the sun's place in the ecliptic, as directed in a previous problem, and bring it to the meridian; turn the globe round, and all the places which pass under that degree of the meridian, will have a vertical sun on that day.

What places will have a vertical sun on the 22d of February? On the 10th of June? On the 16th of September? On the 20th of November? What seas will have a vertical sun on the 9th of May? What large rivers on the 1st of June? What large rivers on the 1st of March?

PROBLEMS ON THE CELESTIAL GLOBE.

PROBLEM XII.—*To find the latitude or longitude of any given star.*

Screw the quadrant on the pole of the ecliptic, bring the star to the meridian, and the degrees of the quadrant, between the ecliptic and star, show the latitude, and the degree of the ecliptic under the graduated edge of the quadrant is the *longtitude.*

Note.—Latitude, on the celestial globe, is reckoned from the ecliptic, north and south. *Longitude* is reckoned on the ecliptic, from the first point of Aries round the globe.

What is the latitude and longitude of Arcturus? *Ans.* Latitude is 31° north; longitude is 201°. What is the latitude and longitude of Regulus? Of Medusa's head? Of Sirius? Of Pollux, in Gemini? Of Antares, in Scorpio? Of Argol, in Perseus? Of Canis Minor?

PROBLEM XIII.—*To find the declination and right ascension of the sun or of a star.*

Bring the place of the sun or of the given star to the brazen meridian, and the degree above it will be its declination; and the number of degrees on the equinoctial under the meridian, reckoned from Aries eastward, is the right ascension.

Note.—Declination is reckoned from the equinoctial, north and south. *Right ascension* is reckoned on the equinoctial from the first point of Aries round the globe.

What is the declination and right ascension of the sun on the 19th of April? *Ans.* Declination, 11° 19′; right ascension, 27° 30′. What is the declination and right ascension of the sun on the 2d of December? On the 18th of February? On the 4th of March? On the 10th of May? Of the star Aldebaran, in Taurus? Of Argol, in Perseus? Of Arcturus, in Bootes?

PROBLEM XIV.—*To find the place of a heavenly body on the globe, when the latitude and longitude are given.*

Place that part of the quadrant of altitude marked o, on the given longitude in the ecliptic, and the upper end over the pole of the ecliptic; and under the given latitude will be found the star required.

What is the star whose longitude is 201°, and its latitude 31° north? *Ans.* Arcturus, in Bootes. What star is that which has a longitude of 209°, and a latitude of 29° north? That which has a longitude of 334°, and a latitude of 21° south? That which has a longitude of 107°, and a latitude of 10° north? That which has a longitude of 66½°, and a latitude of 5½° south?

PROBLEM XV.—*To find the place of a heavenly body on the globe when the right ascension and latitude are given.*

Bring the given degree of right ascension to the graduated edge of the brazen meridian, and note the degree. Then immediately under the given declination on the brazen meridian, will be found the place of the star required.

What is the star whose declination is 30° 40′ south, and right ascension 341° 38′? *Ans.* Formalhaut, in the Southern Fish.

What star has a right ascension of 129°, and a declination of 7° north?
What star has a right ascension of 83°, and a latitude of 34° south?
What star has a right ascension of 46½°, and a latitude of 10° south?
What star has a right ascension of 110½°, and a latitude of 32° north?

PROBLEM XVI.—*To find the distance in degrees between any two given stars on the globe.*

Lay the quadrant of altitude over the two given stars, and the number of degrees between them, as reckoned on the quadrant, will be their distance as seen from the earth. Or, extend a thread over any two given stars, apply the distance found to the equator, and count the number of degrees.

What is the distance between Pollux, in Gemini, and Altair? Between Castor and Pollux? Between Arcturus and Procyon? Between Sirius and Deneb? Between Regel and Sirius?

A DICTIONARY

OF

ASTRONOMICAL TERMS.

ABERRATION (*aberro*, to wander from). The apparent motion of the heavenly bodies, produced by the progressive motion of light and the earth's annual motion in its orbit.

ABSOLUTE EQUATION. The sum of the optic and eccentric equations.

ACCELERATION (*accelero*, to hasten). The augmentation or increase of motion in accelerated bodies.

1. *Acceleration of a planet.* A planet is said to be accelerated when its real diurnal motion exceeds its mean diurnal motion.

2. *Acceleration of the moon.* A term used to express the increase of the moon's mean motion from the sun, it being somewhat greater now than formerly.

3. *Diurnal acceleration of the fixed stars.* The time by which the stars, in one diurnal revolution, anticipate the mean diurnal revolution of the sun; which is 3′ 55″ 9‴.

ACHRONYCHAL (*akros*, extreme, *nux*, night). A Greek term applied to a star, or planet, when it is opposite to the sun. A star *rises achronychally*, when it rises at sunset; and *sets achronychally* when it sets at sunrise.

ALMANAC. A calendar, wherein the days of the month, festivals, lunation, motions of the heavenly bodies, eclipses, &c. are set down for each year.

ALTITUDE OF A CELESTIAL BODY. The arc of a vertical circle, measured from the horizon.

AMPHISCII, or AMPHISCIANS (*amphi*, on both sides, *skia*, a shadow). A Greek designation of the people who inhabit the torrid zone, so called because they have their shadows at noon, turned sometimes one way, and sometimes another, or north and south.

AMPLITUDE (*amplus*, large). An arc of the horizon intercepted between the east or west point, and the centre of the sun or star, at its rising or setting.

ANALEMMA (*analambano*, to take up). A projection of the sphere on the plane of the meridian made by straight lines and ellipses, the eye being supposed at an infinite distance, and in the east and west points of the horizon.

ANGLE. The inclination of two lines meeting one another in a point, called the *vertex*. The lines are called the legs or sides of the angle. Angles, in geometry, are called *right*, *acute*, and *obtuse*. A right angle contains just 90 degrees, or the quarter part of a circle. Acute angles contain less, and obtuse angles more, than 90 degrees.

1. *Angle of commutation.* The angle at the sun, formed by two lines, one drawn from the earth, and the other from the place of the planet reduced to the ecliptic, meeting in the sun's centre.

2. *Angle of elongation.* The angle formed by two lines drawn from the earth, the one to the sun, and the other to the planet; or it is the difference between the sun's place and the geocentric place of the planet.

3. *Angle of evection.* An inequality in the motion of the moon, by which,

at or near her quadratures, she is not in the line drawn through the centres of the earth and sun, as she is at the syzygies, but makes an angle with that line of about 2° 51′.

ANGULAR MOTION. The motion of the planets about the centre of the sun, or that of the satellites about the centres of their primaries.

ANNUAL ARGUMENT. An arc of the ecliptic comprehended between the sun's place and that of the moon's apogee.

ANNUAL EPACT. The excess of the solar year above the lunar, which is 10 d. 21 h. 11 m. or nearly 11 days, which shows that the moon changes so much sooner in any month of the subsequent year, than it did the year before.

ANNUAL EQUATION. The difference between the planet's mean and true place.

ANOMALISTICAL YEAR. The time from the sun's leaving its apogee, till it returns to it again, which is 365 days 6 h. 15 m.

ANOMALY (*anomalos*, Gr. uneven). The distance of a planet in degrees, minutes, and seconds, from the aphelion or apogee.

ANSE or ANSES. The seemingly prominent parts of the ring of Saturn, which are seen at its opening.

ANTARCTIC CIRCLE (*anti*, against, *arctos*, the bear). An imaginary line extending round the south pole, 66½ degrees from the equator, and parallel to it.

ANTARCTIC POLE. The south pole, or the southern extremity of the earth's axis.

ANTECEDENTIA. A term made use of to signify that a planet moves retrograde, or contrary to the order of the signs; that is, from east to west.

ANTIŒCI, or ANTŒCIANS (*anti*, against, *oikos*, a habitation). Those who live under the same meridian, and at the same distance from the equator, but one having north, and the other south latitude.

ANTIPODES (*anti*, against, *podes*, feet). The people of two places diametrically opposite to each other; they differ in longitude 180°, and one has the same latitude north, as the other has south.

APHELION (*apo*, from, *helios*, the sun). That point of a planet's orbit which is most distant from the sun. Its opposite point is the *perihelion*, which is the nearest point to the sun.

APOGEE (*apo*, from, *ge*, the earth). The sun's or the moon's greatest distance from the earth.

APPARENT (*appareo*, to appear). That which is visible or evident to the eye.

1. *Apparent conjunction of the planets* is when they have the same geocentric longitude. The apparent conjunction of the moon with any of the heavenly bodies, is their conjunction as seen from the surface of the earth.

2. *Apparent diameter of the heavenly bodies* is their angular diameter as seen from the earth, measured with a micrometer.

3. *Apparent distance of two celestial bodies* is their angular distance as seen from the earth. *Apparent* horizon is that circle which limits our sight, and has its plane parallel to the true horizon, passing through the centre of the earth.

APPULSE. The near approach of two celestial bodies to each other in angular distance, so as to be seen, for instance, within the field of a telescope.

APSES, or APSIDES (*apsis*, a circle or curvature). The two points in the orbits of the planets, or satellites, which are at the greatest and least distance from the centre of motion; and a line joining these two points is called the line of the apses.

ARC. A part of a curved line, or circle; for example, the latitude and declination are arcs of the meridian, and longitude is the arc of the equator or parallel circle.

1. *Arc of direction* is that arc which a planet appears to describe when its motion is direct or progressive.

2. *Arc of retrogradation* is that which a planet describes whilst moving contrary to the order of the sign, or from east to west.

ARCTIC CIRCLE (*arctos*, a bear). An imaginary line extending round the north pole, 66½ degrees from the equator, and parallel to it. This and the antarctic circle are called polar circles.

ARGUMENT. An arc given, by which another may be found in some proportion to it.

Argument of latitude. An arc of the orbit of a planet, intercepted between the ascending node, and the place of the planet from the sun, according to the order of the signs.

ARIES. A constellation of fixed stars, drawn on the globe in the figure of a *ram*. It is the first of the twelve signs of the zodiac, from which a twelfth part of the ecliptic takes its name. It consists of sixty-six stars.

ARMILLARY SPHERE. A name given to an artificial sphere, representing the several circles of the system of the world.

ASCENDING. A term denoting any star, degree, or any point of the heavens, rising above the horizon.

1. *Ascending latitude* is the latitude of the moon or planet when going northward.

2. *Ascending node* is the point of a planet's orbit, where it cuts the ecliptic in going northward; it is marked ☊.

ASCENSION. The rising of the sun or star, or any part of the equinoctial with it, above the horizon.

ASCENSIONAL DIFFERENCE. The difference between the right and oblique ascension, or descension; or the interval of time in which the sun rises or sets, before or after six o'clock.

ASCII (*a*, not, *skia*, shadow). The inhabitants of the torrid zone, who at certain times of the year have no shadow.

ASPECT. The situation of the stars or planets with respect to each other. There are reckoned five aspects, viz. *Conjunction*, ☌; *Sextile*, ✱; *Quartile*, □; *Trine*, △; *Opposition*, ☍. A ☌ $=0^\circ=0^s$, *a* ✱ $=60^\circ=2^s$, *a* □ $=90^\circ=3^s$, *a* △ $=120^\circ=4^s$, and ☍ $=180^\circ=6^s$.

ASTEROIDS (*aster*, a star, *eidos*, likeness). A general term applied by Dr Herschel to the new planets, Ceres, Juno, Pallas, and Vesta, in consequence of their being found to deviate very much in the form and position of their orbits from those of the old planets.

ASTROLABE (*astron*, a star, *lambano*, to take). A stereographic projection of the sphere upon the plane of one of the great circles. The *Sea Astrolabe* is an instrument used for the altitude of the sun and stars.

ASTROLOGY (*astron*, a star, *logos*, an account). A pretended art of foretelling future events by the aspects and positions of the stars.

ASTRONOMY (*aster*, a star, *nomos*, law). The science which teaches the motions of the earth, the sun, the moon, planets, comets, and stars, and explains the phenomena occasioned by those motions.

ASTROCOPE (*astron*, a star, *skopeo*, to look). An astronomical instrument invented by W. Shuckhard.

AURORA BOREALIS or NORTHERN LIGHTS. A kind of meteor of a pale colour, sometimes seen in the northern parts of the heavens, supposed to be an electrical phenomenon.

AUSTRAL, SOUTHERN. The six signs of the zodiac, which are south of the equinoctial, are called *Austral signs*.

AUTUMN. The third quarter of the year, which begins when the sun enters *Libra*, that is, about the 21st or 22d of September, when the days and nights are equal.

AUTUMNAL EQUINOX. The time when the sun enters Libra, or the descending point of the ecliptic, called also the *Autumnal point.* The signs *Libra, Scorpio* and *Sagittarius*, are called autumnal signs.

AXIS. An imaginary line which passes through the centre of a body, and on which it turns.

1. *Axis of the earth.* An imaginary line conceived to pass through the centre of the earth from one pole to the other, about which is performed its diurnal rotation from west to east.

2. *Axis of the circles of the sphere.* Right lines supposed to be drawn through their centres, perpendicular to their planes.

AZIMUTH. (Arabic). An arc of the horizon intercepted between the meridian and a vertical circle passing through the body.

AZIMUTH COMPASS. An instrument for finding the magnetic azimuth or amplitude of a celestial body.

B

B, in the astronomical tables, stands for Bissextile, or Leap-year.

BACK STAFF. An instrument invented by Captain John Davis, a Welshman, about the year 1590; it was used for taking the sun's altitude at sea.

BEARD OF A COMET. The rays which it emits from its head in the direction of its motion.

BISSEXTILE, or LEAP-YEAR. A year consisting of 366 days, which happens every fourth year. The reason for adding a day every fourth year, is because the *tropical* year exceeds the *civil* year six hours. To find *Leap-year*, divide the year by four, and if nothing remains, it is Leap-year. For instance, 1846 divided by 4, gives the quotient 462, and the remainder is two, which shows that the year 1846 is the second *after Bissextile or Leap*-year, and that *1848 will be Leap-year*

BOREAL SIGNS. Those on the north side of the equinoctial, viz. Aries Taurus, Gemini, Cancer, Leo, and Virgo.

C

CALENDAR. See Almanac. There are a great many different calendars, adapted to the various uses of common life, viz. the *Roman calendar*, the *Gregorian calendar*, the *Julian*, the *Reformed*, and the *French new calendar*, &c.

CANCER. The Crab, one of the constellations of the zodiac; when the sun enters this sign, it has the greatest declination northward; it contains eighty-three stars.

CAPRICORN. One of the twelve signs of the zodiac, represented on globes in the form of a goat.

CARDINAL POINTS. The north, south, east, and west points of the horizon.

CARDINAL SIGNS. These are Aries, Cancer, Libra, and Capricorn. The beginning of these signs are in the Cardinal points of the ecliptic.

CATALOGUE OF THE STARS. A table of the fixed stars, arranged according to their right ascensions, or longitudes, with their declinations, or latitudes, together with their annual variations and magnitudes.

CENTRAL FORCES. The powers which cause a moving body to tend towards, or recede from, the centre of motion.

CENTRIFUGAL FORCE (*centrum*, the centre, *fugio*, to avoid). The force by which all bodies, that move round any other body in a curve, endeavour to fly off from the axis of their motion in a tangent.

CENTRIPETAL FORCE (*centrum*, the centre, *peto*, to seek). That force by which a body tends towards some point as a centre: such is gravity, or that force whereby bodies tend towards the centre of the earth; and that force, whatever it be, whereby the planets are continually drawn back from right-lined motions, and made to move in curves.

CERES, or PIAZZI. A primary planet moving between the orbits of Mars and Jupiter; it was discovered on the 1st of January, 1801, by M. Piazzi.

CHARACTERS. Certain marks used in the sciences, as abbreviations. The astronomical characters are the following: *The twelve signs of the zodiac*, are ♈ Aries, the Ram; ♉ Taurus, the Bull; ♊ Gemini, the Twins; ♋ Cancer, the Crab; ♌ Leo, the Lion; ♍ Virgo, the Virgin; ♎ Libra, the Balance; ♏ Scorpio, the Scorpion; ♐ Sagittarius, the Archer; ♑ Capricornus, the Goat; ♒ Aquarius, the Water-bearer; ♓ Pisces, the Fishes. *The planets*, ☉ The Sun; ☿ Mercury; ♀ Venus; ⊕ Earth; ♂ Mars; ⚶ Vesta; ⚵ Juno; ⚳ Ceres; ⚴ Pallas; ♃ Jupiter; ♄ Saturn; ♅ Uranus. *The Aspects.* ☌ Conjunction; ⚹ Sextile; □ Quartile; △ Trine; ☍ Opposition. *The Nodes.* ☊ Ascending node; ☋ Descending node. *Motion* and *Time.* ° Degree; ′ minute; ″ seconds; ^{h} hour; ^{m} minute; ^{s} second; A.M. Ante Meridian, or before noon; P.M. Post Meridian, or afternoon. Sometimes M. is put for morning, and A. for afternoon.

CHRONOMETER (*chronos*, time, *metron*, a measure). An instrument contrived for the purpose of measuring small portions of time; or watches used for finding the longitude are generally called chronometers, or time-keepers.

CIRCLE. A plane figure comprehended by a single curved line, called its circumference, to which right lines or radii, drawn from a point in the centre, are equal to each other.

1. *Circles of the sphere.* Circles whose planes pass through the sphere, and have their circumference upon its surface. *If the plane pass through the* centre of the sphere, it is called a great circle, if not, it is called a less circle. The equator and ecliptic are great circles; the polar circles and the parallels of latitude or declination, are small circles.

2. *Circles of declination.* Great circles perpendicular to the equinoctial.

3. *Circle of illumination.* That imaginary circle which divides the enlightened hemisphere of the earth from the darkened.

4. *Circles of latitude*, or *secondaries to the ecliptic.* Great circles perpendicular to the ecliptic, and intersecting in its poles.

5. *Circles of longitude.* See LONGITUDE.

6. *Circles of perpetual apparition.* Small circles parallel to the equator, and touching the horizon of any given place.

7. *Circles of perpetual occultation.* Small circles parallel to the equator, and touching the lower part of the horizon, or never appearing above it.

8. *Circles of position.* Great circles of the sphere, passing through the common intersection of the meridian and horizon, and through any degree of the ecliptic, or centre of a star or planet.

9. *Circles of altitude.* See VERTICAL CIRCLES.

CIRCUMPOLAR STARS. Stars which revolve round the pole, without setting in a given latitude.

CIVIL DAY. The time allotted for day in civil purposes; it begins differently in different nations; it is divided into twenty-four hours.

CIVIL MONTH. The same as given in the common almanacs.

CIVIL YEAR. That which is appointed by any government, to be used within its own dominions.

CLOCK. A well known machine for measuring time, regulated by the uniform motion of a pendulum. Common clocks are made to show mean solar time, but those used at observatories, for the purpose of observing the time of the stars transiting the meridian, show sidereal time.

CLOUDS. A collection of misty vapours suspended in the air. Their various colours and appearances are owing to their particular situation in regard to the sun, to the different reflection of the sun's rays, and to the effects produced on them by wind.

COLURES (*kolouros*, a truncated tail). Two great circles or meridians, which surround the globe from north to south, and pass through the poles of the world, cutting each other at right angles; the one is called the *equinoctial colure*, and passes through the beginning of Aries and Libra; the other, called the *solstitial colure*, passes through the beginning of Cancer and Capricorn. They divide the ecliptic into four equal parts, and make the four seasons of the year. The name probably suggests that a portion of them is always concealed from view under the horizon. But this is true of every other meridional circle.

COMET (*kometes*, from *kome*, hair). A celestial body, frequently called a blazing star, moving in a very eccentric orbit, having a vapour-like appendage. The comet moves in the planetary regions, appearing and disappearing at very uncertain intervals of time.

COMETARIUM. A machine showing the motion of a comet about the sun.

COMMUTATION. See Angle of Commutation.

COMPLEMENT. The distance of a star from the zenith; or the arch comprehended between the place of the star above the horizon and the zenith.

COMPLEMENT OF AN ARC OR AN ANGLE. This denotes what an arc or angle wants of 90°; thus we say, the complement of altitude or coaltitude, which is the zenith distance; the complement of latitude or declination, *which is the polar distance.*

CONJUNCTION. The meeting of two stars or planets in the same degree of the zodiac. The conjunction of two celestial bodies denotes that they have the same degree of longitude.

CONSEQUENTIA. A term applied when the planets move according to the order of the signs.

CONSTELLATION. A system of several stars which are seen in the heavens near to one another. Astronomers not only mark out the stars, but they distribute them into asterisms, or constellations, allowing several stars to make up one constellation:—and for the better distinguishing and observing them, they reduce the constellations to the forms of objects with which we are well acquainted.

COSMICAL RISING AND SETTING. A term applied when a star rises or sets at the time of sunrise.

COSMOGRAPHY (*kosmos*, the universe, *grapho*, to describe). A description of the world, showing the structure of the heavens, with the disposition of the stars, and parts of the earth.

CULMINATION (*culmen*, the top). The transit or passage of a star over the meridian.

CURTATE DISTANCE of a planet from the earth or sun. The distance of the earth or sun from that point where a perpendicular passing the planet cuts the ecliptic.

CYCLE (*kuklos*, Gr. a circle). A certain period of time, in which the same revolutions begin again; a periodical space of time.

1. *Cycle of indiction*, or Roman indiction. This cycle has no connexion with the celestial motions; it is a period of 15 years. To find this cycle, add three to the given year, and divide the sum by fifteen, and what remains is the indiction.

2. *Cycle of the moon*, or the *lunar cycle*. A period of nineteen years, in which the new and full moons return on the same days as they did nineteen years before; this cycle is called the

Golden Number, for the finding of which, see Golden Number.

3. *Cycle of the sun.* A period of 28 years, in which time the days of the month return again to the same days of the week, &c. See Solar Cycle.

D

DAY. In common language, the day is the interval of time which elapses from the rising to the setting of the sun; this is called an artificial day. The astronomical day embraces the whole interval which passes during a complete revolution of the sun.

DECLINATION. The distance of any celestial object from the equinoctial, either northward or southward. It is either true or apparent, according as the real or apparent place of the object is considered.

Declination circles. Great circles perpendicular to the equinoctial, and passing through its poles.

DEGREE. A division of a circle, including a three-hundred-and-sixtieth part of its circumference. Every circle is supposed to be divided into three hundred and sixty parts, called degrees, and each degree divided into sixty other parts called minutes; and each of these into sixty seconds.

DEPRESSION OF THE POLE. When a person sails or travels towards the equator, he is said to depress the pole, because as many degrees as he approaches nearer the equator, so many degrees will the pole be nearer the horizon. The phenomenon arises from the spherical figure of the earth.

DEPRESSION OF THE SUN or STAR. Its vertical distance below the horizon.

DESCENDING NODE. That point of a planet's orbit, where it cuts the ecliptic, proceeding southward, marked ☋.

DESCENSION. See Oblique and Right.

DIAL. An instrument to show the hour of the day by the sun.

DIAMETER (*dia*, through, *metron*, a measure). A right line passing through the centre of a circle, and terminated at each side by the circumference thereof.

DIGIT (*digitus*, a finger). The twelfth part of the diameter of the sun or moon; a term used to express the quantity of an eclipse. Thus an eclipse is said to be six digits, when six of these parts are hid.

DIRECT. See Consequentia.

DIRECTION. The line or path of a body's motion, along which it endeavours to proceed, according to the force impressed upon it.

DISK. The body and face of the sun and moon, such as it appears to us on the earth, or the body or face of the earth, such as it appears to a spectator in the moon. The disk in eclipses is supposed to be divided into twelve equal parts.

DISK OF THE EARTH. The difference between the horizontal parallax of the sun and moon; used in the construction of solar eclipses.

DISTANCE OF THE SUN, MOON, AND PLANETS. The real distances of any of these as found by their parallaxes.

DIURNAL. Something relating to the day, in opposition to nocturnal, which regards the night. The diurnal motion of a planet, is so many degrees and minutes as any planet moves in twenty-four hours. Hence the motion of the earth about its axis is called its diurnal motion.

1. *Diurnal arc*, is the arc described by the celestial bodies from their rising to their setting.

2. *Diurnal motion*, is the degrees, minutes, or seconds, a celestial body describes in twenty-four hours.

3. *Diurnal motion* of the earth, is its rotation on its axis.

DOMINICAL LETTER. One of

the first seven letters of the alphabet, wherewith the Sundays are marked in the almanacs with a red letter throughout the year.

E

EARTH, or TERRA. One of the planets: its orbit lies between Venus and Mars. Its diameter is 7914 miles, and observation proves it to be inhabited.

EARTHQUAKE. A sudden motion of the earth, occasioned, it is supposed, either by the discharge of some electrical power, or by large quantities of inflammable air, which, on being rarefied by internal fires, forces its way through the parts that surround it.

EAST. One of the four cardinal points of the world; being that point of the horizon where the sun is seen to rise when in the equinoctial.

ECCENTRIC (*ex*, out, *kentron*, the centre). A term applied to circles and spheres which have not the same centre, and consequently are not parallel; in opposition to concentric, where they are parallel, having one common centre.

ECCENTRICITY. The distance of the centre of the orbit of a planet from the centre of the sun; that is, the distance between the centre of the ellipsis and the focus.

ECLIPSE (*ekleipo*, Gr. to leave out). The deprivation of the light of the sun, or of some heavenly body, by the interposition of another heavenly body between it and our sight.

ECLIPTIC. A great circle of the sphere, supposed to be drawn through the middle of the zodiac, making an angle with the equinoctial of 23 degrees 30 minutes; or it is that path among the fixed stars, that the earth appears to describe, to an eye placed in the sun, in performing its annual motion round the sun.

ELEMENTS. Principles deduced from observation, by which tables of the planetary motions are computed.

ELEVATION OF THE POLE or STAR. The height of the pole or stars in degrees above the horizon.

ELLIPSIS (*elleipo*, Gr. to leave out). A curved line returning into itself, and produced from the section of a cone by a plane cutting both its sides, but not parallel to the base.

EMERSION. A term employed when any planet which is eclipsed begins to emerge or get out of the shadow of the eclipsing body. It is also used when a star, before hidden by the sun, as being too near him, begins to re-appear, or emerge out of his rays.

EPACT. See ANNUAL and MENSTRUAL EPACTS.

EPHEMERIS (*epi*, for, *hemera*, a day). Tables containing the computations of the places of the heavenly bodies for every day at noon.

EQUATION OF THE MOON'S MEAN MOTION. This depends upon the situation of the moon's apogee and nodes with respect to the sun.

EQUATION OF TIME. The difference between apparent and mean time, or between the sun's mean motion and right ascension.

EQUATOR (*æquo*, to equal). An imaginary circle equally distant from the poles, and dividing the earth into two equal parts, one being called the Northern hemisphere, and the other the Southern hemisphere.

EQUATORAL. A very useful instrument in Astronomy, for taking the altitude, azimuth, right ascension, &c. of the heavenly bodies.

EQUINOCTIAL (*æquæ noctes*, equal nights). A great circle of the celestial globe, whose poles are the poles of the world. It is so called, because, whenever the sun comes to this circle, the days and nights are equal all over the globe; being the same with that which the sun seems to describe at the time of the two equinoxes of spring and autumn.

EQUINOCTIAL POINTS. These are *Aries* and *Libra;* and when the sun enters either of these points, it is called the equinox.

EQUINOX. The time when the sun enters either of the equinoctial points, where the ecliptic intersects the equinoctial.

ERA, or EPOCH. A fixed point of time from which to begin the computation of the ensuing years.

EVECTION. See ANGLE OF EVECTION.

F

FACULÆ. Certain bright spots, frequently seen upon the disk of the sun.

FALCATED. The moon or a planet is said to be falcated, when the enlightened part appears of a crescent form like the moon or Venus, when near the sun.

FIXED SIGNS OF THE ZODIAC. These are Taurus, Leo, Scorpio, and Aquarius; they are so called because the season is considered to be more settled when the sun passes through these signs, than at any other times of the year.

FIXED STARS. Such as do not appear to change their relative situations. They are properly called stars, in contradistinction to planets and comets.

FOCUS. A term applied in geometry and conic sections, to certain points in the parabola, ellipsis, and hyperbola, where the rays reflected from all parts of these curves concur and meet.

FORE STAFF. An instrument used at sea for taking the altitudes of the celestial bodies. It is now superseded by the use of more perfect instruments.

FRIGID ZONES. The spaces on the earth's surface between the polar circles and the poles.

G

GALAXY (*gala*, Gr. milk). A whitish track which appears to encompass the heavens; it is very visible during a bright night, when the moon is absent. Dr Herschel found it to consist of innumerable small stars and nebulous matter.

GEMINI. A zodiacal constellation in the northern hemisphere, containing eighty-five stars.

GEOCENTRIC (*ge*, the earth, *kentron*, the centre). A term literally signifying, having the earth for its centre.

1. *Geocentric place of a planet.* Its place as seen from the earth.

2. *Geocentric latitude of a planet.* Its perpendicular distance from the ecliptic as seen from the earth.

3. *Geocentric longitude of a planet.* Its elliptical distance from the first point of Aries, as seen from the earth.

GIBBOUS (*gibbus*, protuberant). A term used in reference to the enlightened parts of the moon, whilst she is moving from her first quarter to the full, and from the full to the last quarter.

GLOBE. A round or spherical body, more usually called a sphere, bounded by one uniform convex surface, every point of which is equally distant from a point within, called the centre.

GNOMON. An apparatus used by the ancients for finding the altitudes and declinations of the celestial bodies.

GOLDEN NUMBER, or CYCLE OF THE MOON, which see. To find the Golden Number for any year, for example, 1819: First, $1819+1=1820$; this divided by 19, gives 95, and 15 for the remainder, which is the Golden Number, as required.

GREGORIAN CALENDAR. The reformed calendar now in use, which takes its name from Pope Gregory the XIIIth.

GREGORIAN EPOCH. The time when the Gregorian computation first took place, which was in the year 1582.

GREGORIAN TELESCOPE. A reflecting telescope, having a hole in the centre of the great speculum, through which the image is thrown by the small reflector to the eye. The distinctness of the object seen through this telescope is somewhat diminished by the hole in the great speculum.

GREGORIAN YEAR. The year now in use, called the new style; it consists of 365 days for three years, and 366 every fourth year, the same as the Julian account; but as this exceeds the tropical year by about eleven minutes and one-twentieth, and which in Pope Gregory's time amounted to ten days, he ordered so many days to be struck out of the calendar; and to prevent the like anticipation in future, it was ordered that every century not divisible by four, be reckoned common years, which in the Julian account are bissextile.

H

HEAVEN. The infinite expanse in which the stars, planets, and comets, are situated, or perform their respective revolutions.

HELIACAL RISING AND SETTING OF A STAR. A term applied when a star rises or sets with the sun. Or a star is said to rise heliacally when it is first seen after conjunction with the sun, and to set heliacally when it is so near the sun as to be hid by his beams.

HELIOCENTRIC PLACE OF A PLANET (*helios*, the sun, *kentron*, centre). Its latitude and longitude, or place in the heavens, as seen from the sun. The heliocentric motion of a planet is always direct, the sun being its centre of motion.

HELIOMETER (*helios*, the sun, *metron*, a measure). A kind of micrometer for measuring the diameter of the sun, moon, and stars.

HEMISPHERE (*hemi*, half, *sphaira*, a sphere). The half of a globe or sphere, when it is supposed to be cut through its centre in the plane of one of its great circles. The equator or equinoctial divides the sphere into two equal parts, called the northern and southern hemispheres.

HETEROSCII (*heteros*, other, *skia*, shadow). The inhabitants of the two temperate zones, whose shadows at noon are always projected the same way with regard to themselves, or always contrary ways with respect to each other.

HORIZON (*horizo*, Gr. to bound). That great circle which divides the heavens and the earth into two equal parts or hemispheres, distinguishing the upper from the lower. The horizon is either sensible or rational—the sensible horizon is that circle which terminates or bounds our view; the rational is that which divides the Starry Heavens into the upper and lower hemispheres; the stars in the upper being those that are visible, and in the lower those that are invisible to us.

HORIZONTAL. Something relating to the horizon; or that is taken in, or on a level with, or parallel to the horizon. Thus, we say, a horizontal plane.

HORIZONTAL PARALLAX. The parallax of a celestial body, when in the horizon. See PARALLAX.

HOUR. The 24th part of a natural day, answering to 15° of the equator.

I

IMMERSION. A term applied when a star or planet is so near the sun, with regard to our observations, that we cannot see it; being as it were enveloped or hidden in the rays of that luminary. It also denotes the beginning of an eclipse of the sun or moon, when either of those bodies begins to be darkened by the shadow of the other. The term is frequently used in reference to Jupiter's satellites; when the satellite enters the shadow of the planet, it is called its immersion.

INCLINATION OF THE ORBIT OF A PLANET. The angle which the plane of the planet's orbit makes with the plane of the ecliptic, or earth's orbit.

INDICTION. See Cycle of Indiction.

INFORMED STARS. Such as were formerly not included in constellations; but modern astronomers have contrived to include all the informed stars.

INGRESS. The sun's entering any of the twelve signs, or other parts of the ecliptic.

J

JULIAN YEAR. The year established by Julius Cæsar, now called the old style. See Gregorian Year.

JUNO, or HARDING PLANET. One of the newly discovered planets, and the sixth in order from the sun; it was first discovered in 1804.

JUPITER. The name of one of the primary planets, remarkable for its great brightness.

L

LATITUDE (*latus*, broad). The distance of a place from the equator, or an arc of the meridian intercepted between the zenith of the place and the equator. It can never exceed 90 degrees, as that is the distance of the poles from the equator. Hence latitude is either northern or southern, according as the place, whose latitude is spoken of, is on this or that side of the equator.

LATITUDE, in astronomy. The distance of a star or planet from the ecliptic, in degrees, minutes, and seconds, measured on a circle of latitude drawn through that star or planet, being either north or south, as the object is situated on the north or south side of the ecliptic.

LATITUDE OF THE MOON. The *perpendicular distance* of the moon from the plane of the ecliptic; it is north latitude, when she is on the north side of the ecliptic, and south latitude, when on the south side. It is *north ascending*, from the ascending node to her northern limit; and *north descending*, from the northern limit to the descending node. It is *south ascending*, from her southern limit to the ascending node; and *south descending*, from the descending node to her southern limit. And the like is to be understood of the planets.

LEAP-YEAR. See Bissextile

LEE. An epithet to distinguish that half of the horizon to which the wind is directed, from the other part where it arises, which latter is accordingly called to windward.

LIBRA (a balance). The name of one of the twelve signs of the zodiac, the sixth in order; so called because, when the sun enters it, the days and nights are equal, as if weighed in a balance.

LIBRATION (*libro*, to balance). An apparent inequality of the moon's motion, whereby she seems to librate about her axis, sometimes from the east to the west, and now and then from the west to the east; so that the parts in the western limb or margin of the moon sometimes recede from the centre of the disk, and sometimes move towards it, by which means they become alternately visible and invisible to the inhabitants of the earth.

LIMIT OF A PLANET. This signifies its greatest heliocentric latitude.

LONGITUDE (*longus*, long). The distance of a place situated to the east or west of some noted meridian, as that of Greenwich: it can never exceed 180 degrees, which is half the circumference of the earth.

LUNAR (*luna*, the moon). Something belonging to the moon; thus we say, lunar month, lunar year, lunar dial, or lunar eclipse.

LUNAR DISTANCE. A term used

in nautical astronomy, for the distance of the moon from the sun, or fixed stars; the measurement of which, whereby the true distance can be computed, is found to be of the greatest use in determining the longitude.

LUNATION. The time or period from one new moon to another—it is called the synodical month.

M

MACULÆ. Dark spots that are frequently seen upon the disk of the sun.

MAGNITUDES. The fixed stars, according to their size or brightness, are divided into magnitudes; the brightest are called stars of the first magnitude; the next in brightness, stars of the second magnitude; and so on to the sixth or seventh magnitudes, which are the smallest that can be seen with the naked eye.

MARS. The name of the planet which revolves next beyond the earth in our system; it is of a red fiery colour, and always gives a much duller light than Venus, though sometimes he equals her in size.

MEAN ANOMALY OF A PLANET. Its angular distance from the aphelion or perihelion, supposing it to revolve in a circle with its mean velocity.

MEAN CONJUNCTION OF THE SUN AND MOON. The conjunction of their mean longitudes.

MEAN DISTANCE OF A PLANET. The semi-transverse diameter of its orbit.

MERCURY. The name of a small star which emits a very bright white light, though, by reason of his always keeping near the sun, he is seldom to be seen; and when he does make his appearance, his motion towards the sun is so swift, that he can only be *discerned for* a short time.

MERIDIAN (*meridies*, mid-day). A *great circle passing* through the poles of the world, and both zenith and nadir, crosses the equinoctial at right angles, and divides the sphere into two hemispheres, the eastern and western; it has its poles in the east and west points of the horizon. It is called meridian, because, when the sun comes to the south part of this circle, it is then midday; and then the sun has his greatest altitude for that day.

MICROMETER (*mikros*, small, *metron*, a measure). An instrument fitted to a telescope, for the purpose of measuring small angles, such as the diameters of the celestial bodies.

MID-HEAVEN, or MEDIUM CÆLI. That point or degree of the ecliptic, which is upon the meridian at any time.

MILKY WAY. See GALAXY.

MINUTE. The sixtieth part of a degree of a circle. Minutes are denoted by one acute accent, thus (′); the second, or sixtieth part of a minute, is by two such accents, thus, (″); and the third by three (‴).

MONTH. The twelfth part of a year. A *lunar month* is the time the moon takes to describe the whole circle of the ecliptic, and is $27^d\ 7^h\ 43^m$. A *synodic month*, is the time between two conjunctions of the sun and moon, and is $29^d\ 12^h\ 44^m\ 3^s$. A *solar month* is the mean time of the sun's passing through one entire sign of the ecliptic, which is about $30^d\ 10^h\ 29^m$.

MOON. A satellite, or secondary planet, always attendant on our earth.

MUTUAL ASPECTS. Such as the primary planets make among themselves.

N

NADIR (*nieder*, Ger. down). That point under our feet, or that point of the heavens which is diametrically opposite to the zenith, or point directly over our heads. The zenith and nadir are the two poles of the horizon.

NEBULÆ. Luminous spots in the heavens, some of which consist of clusters of telescopic stars, others appear as luminous spots of different forms. Some of them form a round compact system, others are more irregular, of various forms, and some are long and narrow.

NIGHT. That part of the natural day during which the sun is underneath the horizon; or that space wherein it is dusky.

NOCTURNAL ARC. An arc described by a celestial body during the night.

NODES (*nodus*, a knot). The two points wherein the orbit of a planet intersects the ecliptic, whereof the node, where it ascends northwards, above the plane of the ecliptic, is called the ascending node; and the other, where the planet descends to the south, is called the descending node.

NONAGESIMAL DEGREE. The highest point of the ecliptic above the horizon; this is equal to the angle which the ecliptic makes with the horizon. It is of great use in calculation of eclipses.

NORTH. One of the cardinal points on the compass; that opposite the south.

NUMBER OF DIRECTION. A number not exceeding thirty-five, which number is the limit of Easter day, always falling between the 21st of March, and 25th of April.

NUTATION OF THE EARTH'S AXIS. A kind of vibratory motion, by which its inclination to the plane of the ecliptic is subject to a small variation.

O

OBLATE. Flattened, or shortened, as an oblate spheroid, having its axis shorter than its middle diameter, being formed by the rotation of an ellipse about the shorter axis. The oblateness of the earth refers to the diminution of the polar axis in respect of the equatorial.

OBLIQUE ASCENSION. That point of the equinoctial which rises with a celestial body in an oblique sphere.

OBLIQUE DESCENSION. That point of the equinoctial which sets with a celestial body in an oblique sphere.

OBLIQUE SPHERE. That position of the sphere in which the equator and its parallels cut the horizon obliquely.

OBSERVATORY. A place or building fitted up with proper instruments for observing the celestial bodies.

OCCIDENT. A term applied to the western quarter of the horizon, or that part of the horizon where the ecliptic, or the sun therein, descends into the lower hemisphere, in contradistinction to orient.

OCCIDENTAL. Westerly. A planet is said to be occidental when it sets after the sun.

OCCULTATION (*occulto*, to hide). The time a star or planet is hidden from our sight, by the interposition of the moon, or of some other planet.

OPPOSITION. That aspect of the celestial bodies when they are 180° from each other.

OPTICS. The science of vision, including Catoptrics and Dioptrics, and even Perspective; as also the whole doctrine of light and colours, and all the phenomena of visible objects.

ORBIT (*orbita*, a path). The path of a planet or comet, or the curve that it describes in its revolution round its central body. Thus the earth's orbit is the curve which it describes in its annual course, and usually called the ecliptic.

ORBUS MAGNUS. A term formerly used to signify the orbit of the earth.

ORIENTAL. Easterly. A planet

is said to be oriental, when it rises before the sun.

ORION. The name of a constellation of the southern hemisphere, consisting of thirty-seven stars, according to Ptolemy; of sixty-two, according to Tycho; and of no fewer than eighty, in the Britannic catalogue.

ORRERY. A machine for representing the motions and appearances of the heavenly bodies. It is more properly termed a planetarium.

ORTIVE AMPLITUDE. The eastern amplitude of a heavenly body.

P

PALLAS, or OLBERS. One of the newly-discovered planets, and the eighth in order from the sun.

PARABOLA (*parabole*, Gr. juxtaposition). A geometrical figure arising from the section of a cone, when cut by a plane parallel to one of its sides.

PARADOX (*para*, beside, *doxa*, opinion). A proposition seemingly obscure, as being contrary to some received opinion, but yet true in fact.

PARALLAX (*parallaxis*, Gr. change). A change of the apparent place of any heavenly body, caused by being seen from different points of view: or it is the difference between the true and apparent distance of any heavenly body from the zenith.

PARALLAX HORIZONTAL. See Horizontal Parallax. As the altitude of a body is affected by parallax, so is its right ascension, declination, latitude, and longitude.

PARALLEL. Those straight lines, whose least distances from each other are every where equal, are said to be parallel.

PARALLELS OF ALTITUDE. Small circles parallel to the horizon.

PARALLELS OF DECLINATION.

PARALLELS OF LATITUDE. Small circles parallel to the equinoctial or equator.

PARALLEL SPHERE. That position of the sphere in which the equator is parallel to the horizon.

PARHELION (*para*, beside, *helios*, the sun). A mock sun, or meteor, in form of a very bright light, appearing on one side of the sun.

PENUMBRA (*pene*, nearly, *umbra*, a shadow). A partial shade observed between the perfect shadow and the full light, in an eclipse.

PERIGEE (*peri*, around, *ge*, the earth). That point of the moon's orbit which is nearest to the earth.

PERIHELIUM (*peri*, around, *helios*, the sun). That point of a planet's or comet's orbit wherein it is at its least distance from the sun; in which sense it stands in opposition to aphelium.

PERIOD. The time taken up by a star or planet in making a revolution round the sun; or the duration of its course till it returns to the same point of its orbit.

PERIŒCI (*peri*, around, *oikos*, a habitation). Those who live under the same parallel of latitude, whether north or south, but on opposite meridians.

PERISCII (*peri*, around, *skia*, shadow). The inhabitants (if any) who live within the polar circles.

PHASES (Gr. from *phaino*, to show). The several appearances or quantities of illumination of the Moon, Venus, Mercury, and the other planets; or the several manners wherein they appear illuminated by the sun.

PHENOMENON. Any singular appearance in the heavens, as an eclipse, comet, &c.

PISCES. The last of the zodiacal signs, which contains 113 stars.

PLACE OF A CELESTIAL BODY. This is simply its situation in the heavens, and is usually expressed by its latitude and longitude.

PLANE. A plain surface, or one that lies evenly between its bounding lines—and as a right line is the shortest extension from one point to another, so a plain surface is the shortest extension from one line to another.

PLANET (*planetes*, Gr. a wanderer). A celestial body revolving round the sun, as a centre, and continually changing its position, with respect to the fixed stars; whence the name planet, which is a Greek word, signifying wanderer.

PLEIADES. An assemblage of seven stars in the neck of the constellation Taurus, the bull; although there are now only six of them visible to the naked eye. The largest is of the third magnitude, called "Lucido pleiadum."

POLAR. In general, something relating to the poles of the world, or poles of artificial globes.

POLE. In astronomy, one of the extremities of the axis, on which the sphere revolves. These two points, each ninety degrees from the equinoctial or equator, are by way of eminence called the poles of the world; and the extremities of the axis of artificial globes, corresponding to these points in the heavens, are termed the poles thereof.

PRECESSION OF THE EQUINOXES. This expression denotes a very slow motion of the equinoxes, by which they change their place, going from east to west, or contrary to the order of the signs. This motion amounts to about 50″ in a year.

PRIMARY PLANETS. Those which have the sun for their centre of motion.

Q

QUADRANT (*quadrans*, a fourth part, or quarter). A mathematical instrument, of great service in astronomy, and, consequently, in navigation, for taking the altitudes of the sun and stars, as also for taking angles in surveying.

QUADRATURE. A geometrical term, denoting the squaring or reducing a figure to a square. That position of the moon, when she is 90 degrees from the sun.

QUARTILE ASPECT. See ASPECT.

R

RADIUS VECTOR. That imaginary line connecting the planet and sun, and which, as the planet moves round the sun, describes equal areas in equal times.

REDUCTION. The difference between the planet's orbit, place, or argument of latitude, and ecliptic place.

REFRACTION (*refrango*, to break back). The deviation of a moving body from its direct course, occasioned by the different density of the medium in which it moves; or it is a change of direction, occasioned by a body's falling obliquely out of one medium into another of a different density. Refraction causes the heavenly bodies to appear more elevated above the horizon than they really are.

RETICULA. An instrument invented for ascertaining the quantity of an eclipse.

RETROGRADE. See ANTECEDENTIA.

REVOLUTION. The period of any celestial body.

RIGHT ASCENSION. That point of the equinoctial which comes to the meridian with any celestial body, and is reckoned from the first point of Aries. The degree of the equinoctial, which rises with any celestial body in a right sphere, is called its *right ascension*, and the degree of the equator which sets with any celestial body in the said sphere, is called its *right descension*.

RIGHT SPHERE. That on which the equator and its parallels cut the horizon at right angles.

RISING OF A CELESTIAL BODY. Its appearance above the eastern horizon.

S

SAGITTARIUS. The Archer, one of the zodiacal constellations, containing sixty-nine stars.

SATELLITES. Certain secondary planets, moving round the other planets, as the moon does round the earth. They are so called, because they always attend them, and make the tour about the sun with them.

SATURN. One of the superior planets, formerly considered the most distant in the solar system; it is the tenth in order from the sun.

SCORPIO. The Scorpion, a zodiacal constellation, containing forty-four stars.

SEASONS. The four quarters of the year, viz. Spring, Summer, Autumn, and Winter. The first quarter begins when the sun enters Aries; the second begins when the sun enters Cancer; the third, when he enters Libra; and the fourth, when he enters Capricorn.

SECOND. The sixtieth part of a minute, either of time or of motion.

SECONDARY CIRCLES, or SECONDARIES. All those circles which intersect one of the six great circles of the sphere, at right angles.

SECONDARY PLANETS. See SATELLITES.

SETTING. The going down or disappearance of a celestial body in the western horizon.

SEXTILE ASPECT. See ASPECT.

SHADOW. A privation or diminution of light by the interposition of an opaque body; or it is a plane, where the light is either altogether obstructed or greatly weakened, by the interposition of some opaque body between it and the luminary.

SIDEREAL DAY. The time in which a star appears to revolve from any meridian to the same again, which *is equal to the time of* the earth's per*forming one entire* revolution upon its *axis,* $23^{h}\ 56^{m}\ 4{\cdot}1^{s}$, *of* mean solar time.

SIDEREAL YEAR. The time in which the earth or sun makes one complete revolution in its orbit; that is, from any given star to the same again.

SIGNS. The ecliptic is usually divided, by astronomers, into twelve parts, called signs, each of which, of course, contains thirty degrees. They are usually called signs of the zodiac; and beginning at the equinox, where the sun intersects and rises above the equator, have the following names and marks:—

Aries,	♈	Libra,	♎
Taurus,	♉	Scorpio,	♏
Gemini,	♊	Sagittarius,	♐
Cancer,	♋	Capricornus,	♑
Leo,	♌	Aquarius,	♒
Virgo,	♍	Pisces,	♓

Of these signs, the first six are called northern, lying on the north side of the equator; and the last six are called southern, being situated to the south of the equator.

SIRIUS. The dog-star, one of the brightest stars in the heavens; in the constellation Canis Major.

SKY. The blue expanse of air and atmosphere. The azure colour of the sky is attributed, by Sir Isaac Newton, to vapours beginning to condense there, and which have got consistence enough to reflect the most flexible rays.

SOLAR. Something belonging to the sun; thus the solar system is that system of the world wherein the heavenly bodies are made to revolve round the sun as the centre of their motion.

SOLAR YEAR. This is of two kinds, Tropical and Sidereal, which see.

SOLSTICE (*sol*, the sun, *sto*, to stand). That time when the sun is in one of the solstitial points; that is, when he is at his greatest distance from the equator; thus called, because he then appears to stand still, and not to change his distance from the equator for some time; an appearance owing to the obliquity of our sphere, and to which those living under the equator are strangers. The *solstitial points* are Cancer and Capricorn.

SOUTH. One of the four cardinal points of the compass; when the sun is on the meridian, in northern latitudes, it is then directly south.

SPHERE. A solid contained under one uniform round surface, such as would be formed by the revolution of a circle about the diameter thereof, as an axis.

SPHERE ARMILLARY. See Armillary Sphere, Oblique, and Right Sphere.

SPHEROID (*sphaira*, a sphere, *eidos*, likeness). A solid body approaching to the figure of a sphere.

SPOTS. Certain places of the sun's or moon's disk, observed to be either brighter or darker than the rest, and accordingly called faculæ, or maculæ.

STAR. A general name for all the heavenly bodies which are dispersed throughout the whole heavens.

STATIONARY. A planet is said to be stationary, when it appears to have no motion among the fixed stars.

SUMMER. See Seasons.

SUN. The most conspicuous of the heavenly bodies, which occupies the centre of the system which comprehends the earth, the primary and secondary planets, and the comets.

SYZYGY (*sun*, together, *zeugnuo*, to join). A term equally used for the conjunction and opposition of a planet with the sun.

T

TANGENT. A straight line touching the circumference of a circle in one point; or a right line, which touches any arc of a curve, in such a manner as to make a right angle with the diameter of the circle of which that arc is a part.

TAURUS. The name of one of the twelve signs of the zodiac, the second in order, consisting of forty-four stars, according to Ptolemy; of forty-one, according to Tycho; and of no fewer than one hundred and thirty-five, according to the Britannic catalogue.

TELESCOPICAL STARS. Those stars which are not visible to the naked eve and can be only seen with a telescope.

TERMINATOR. See Circle of Illumination.

TIDES. The periodical flux and reflux of the waters of the sea, supposed to be caused by the action of the sun and moon upon the ocean.

TIME. A certain measure of duration, depending upon the motion of the heavenly bodies.

TORRID ZONE. That space of the earth's surface included between the tropics.

TRANSIT (*transeo*, to pass over). The passing of a planet, just before or over the disk of another heavenly body, as the passing of Mercury or Venus over the sun's disk; the same is said of a planet or star when it passes the meridian.

TROPICS (*trepo*, Gr. to turn). Two circles supposed to be drawn round the earth on each side of the equator, and 23° 29′ distant from it.

TRUE PLACE OF A PLANET. See Heliocentric Place.

TWILIGHT. That light, whether in the morning before sunrise, or in the evening after sunset, which is occasioned by the refraction and reflection of the sun's rays in passing through the atmosphere.

U

UMBRA. The total shadow of the earth, moon, and planets.

URANUS, or HERSCHEL. A superior planet, and the most remote in the solar system.

URSA MAJOR. The Great Bear, a northern constellation, consisting of eighty-seven stars.

URSA MINOR. The Little Bear, a constellation near the north pole, which contains twenty-four stars, one of which is called the pole star.

V

VECTOR. See Radius Vector.

VENUS. The name of the most beautiful star in the heavens, known by the names of the morning and evening star; she keeps near the sun, though she recedes from him almost double the distance of Mercury.

VERTEX. That point in the heavens directly over our heads, called the zenith. The apex of a triangle.

VERTICAL CIRCLE. A great circle perpendicular to the horizon, and passing through the zenith, and nadir of any place.

VESTA. The name of one of the small planetary bodies, discovered lately to revolve between the planets Mars and Jupiter.

VIA LACTEA. See Galaxy.

VIRGO. The name of one of the signs or constellations of the zodiac, and the sixth according to order, containing 110 stars.

Y

YEAR. The time that the sun takes to go through the twelve signs of the zodiac.

Z

ZENITH (*Arabic*). The vertical point; or a point in the heavens directly over our heads. The zenith is called the pole of the horizon, because it is ninety degrees distant from every point of that circle.

ZODIAC (*zodion*, an animal). A broad circle, about eighteen degrees in breadth, whose middle is the ecliptic, and its extremes, two circles, parallel thereto, at such a distance from it, as to bound or comprehend the excursions of the sun and planets.

ZONE (*zona*, a girdle). A division of the terraqueous globe, with respect to the different degrees of heat found in the different parts of it. There are five zones, viz., the torrid, two temperate, and two frigid zones.

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